Electrophysical agents : their nature and therapeutic usage.

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ELECTROPHYSICAL AGENTS:

THEIR NATURE AND THERAPEUTIC USAGE

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ABSTRACT

Ultrasound, shortwave diathermy and laser are used extensively by physiotherapists to treat soft tissue lesions. However, knowledge about their biological effects, clinical efficacy and safety are limited, making the task of selection complex. The purpose of this thesis was to examine the literature about the effects and efficacy of these agents as this information was not known to physiotherapists, explore their usage in clinical practice and investigate the problem solving processes used by clinicians as they select treatments.

An in-depth analysis of the literature was conducted to provide the necessary background to further research; it revealed that information about the effects and efficacy of all three agents is limited and that therapists therefore select treatments under conditions of uncertainty.

Usage was examined through a national survey to a random sample of physiotherapists (n=98); the results revealed that, whilst ultrasound and pulsed shortwave diathermy were used frequently, laser and continuous shortwave diathermy were not. All agents were used to treat open and closed lesions and the signs and symptoms of injury. The majority of respondents reported believing that the agents produced different clinical effects, though this was not confirmed by their reports of recent usage. The main influences affecting selection of agent were (in rank order) the literature, discussion with colleagues, personal experience and courses.

In addition, the size, location, chronicity, depth of the lesion and type of tissue damaged all affected choice.

Problem solving was explored through the use of a process tracing method. The specific tactics and general strategies used by clinicians as they select electrophysical treatments were identified and examined. The results demonstrated that, contrary to previous reports, experienced physiotherapists solving common clinical problems do not primarily use hypothetico-deductive reasoning methods. During the study, all respondents employed similar core cues and selected similar general treatments; however, there was disagreement over the selection of electrophysical treatments.

This work has provided important information not previously available about the use of electrophysical agents in physiotherapy practice.

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LIST OF ABBREVIATIONS

a	Acceleration
ADP	Adenosine diphosphate
amps/m	Amperes per metre
ATP	Adenosine triphosphate
c	Specific heat of tissue
Ca	Calcium
cAMP	Cyclic adenosine monophosphate
CPS	Clinical problem solving
CSWD	Continuous shortwave diathermy
CUS	Continuous ultrasound
DNA	Deoxyribonucleic acid
DWH	Department of Welfare and Health (Canada)
E	Electric field
ECC	Electroconformational coupling
ET	Electrotherapy
F	Force
f	Frequency
GaAl	Gallium arsenide
H	Magnetic field
He-Ne	Helium-neon
Hz	Hertz
I	Intensity
J/cm^2	Joules per centimetre squared
K	Potassium
L	Laser
LLLT	Low level laser therapy
LTM	Long term memory
MHz	Megahertz
m/sec	metres/second
mm	millimetres
µsec	microseconds
Na	Sodium
NAD	Nicotinamide-adenine dinucleotide

NCRP	National Council on Radiation Protection
NHS	National Health Service
nm	nanometres
OA	Osteoarthritis
P	Power
p	Pressure
PMF	Pulsed magnetic field
PSWD	Pulsed shortwave diathermy
PUS	Pulsed ultrasound
Q	Heating power density
R	Ohmic resistance
RNA	Ribonucleic acid
RFEM	Radiofrequency electromagnetic fields
s	Displacement
s	Specific density
SA	Spatial average
SAR	Specific absorption rate
SP	Spacial peak
STM	Short term memory
SWD	Shortwave diathermy
T	Tesla
t	Time
TA	Temporal average
TP	Temporal peak
US	Ultrasound
v	Velocity
W/cm^2	Watts/centimetre squared
w/Kg	watts per kilogram
Z	Acoustic impedance
α	Attenuating co-efficient
α_{ABS}	Absorption co-efficient
λ	Wavelength
ρ	Density

INTRODUCTION

People have always attempted to ease their pains and heal their wounds. To this end many methods have been used, including natural physical agents such as heat, light and magnetic energy (Licht, 1965; Rowbottom and Susskind, 1984; Smith, 1991; Lehmann, 1990). Natural heat and light are both delivered by the sun, and a number of ancient civilisations, including the ancient Egyptians, the Aztec and the Japanese, elevated the sun to the rank of deity. Heliotherapy was advocated by Greek and Roman physicians such as Celsus and Galen for the treatment of arthritis, asthma, epilepsy and obesity, and Herodotus noted the links between sunlight and bone development in the fifth century BC (Licht, 1983). The presence of magnetism was noted early in history in both the loadstone and amber, and the Ancient Greeks suggested that these materials possessed a soul, as they were able to attract materials to it. Later, in the 16th century, both Franz Anton Perkins and Professor Höll advocated cures using magnetism which, they said, acted on invisible fluids within the body to affect health. Other forms of electrical stimulation, arising from natural sources such as the Torpedo ray and South American electric eel, were used to relieve pain and influence healing (Rowbottom and Susskind, 1984).

Later Galvani (1737-1798) 'discovered' the electrical current, with the result that, during the nineteenth century, artificial electrophysical methods of treatment became available (Rowbottom and Susskind, 1984). They were hailed as the miracle cures of the day and included such novelties as Dr. Scotts' Electric Plasters, J Moses' Patent Electro Galvanic Spectacles and Electromagnetic Hairbrushes (Barker and Freeston, 1985). Claims made for the value and efficacy of these commodities were no less imaginative; they included statements such as 'electricity is life' and claims that 'the organ of sight (could be) restored to its original strength' and that 'heart troubles, rheumatism, neuralgia, paralysis, weakness, nervousness, lumbago, sciatica (could be) quickly cured' (Barker and Freestone, 1985).

Present day forms of electrophysical treatment have developed from these unlikely beginnings and are now commonly used in the management of pain and soft tissue lesions. Such use began early this century (Lehmann, 1990), and the developing profession of physiotherapy adopted a number of agents as part of its treatment repertoire. Modalities such as infrared, galvanic stimulation and long wave diathermy were used to treat a wide range of conditions including ulcers, incontinence, elephantiasis and poliomyelitis (Fleck, 1952; Licht, 1965). Gradually other agents were introduced so that by the nineteen sixties continuous shortwave diathermy, microwave diathermy, infrared irradiation, faradic stimulation, direct current stimulation and ultraviolet irradiation were in common use (Licht, 1958; 1965; Scott, 1969). Since that period ultrasound, pulsed shortwave and microwave diathermy and, most recently, low level laser have increasingly been used in general clinical practice (Ohshiro and Calderhead, 1988; Lehmann, 1990; Low and Reed, 1990).

Subjects suffering from soft tissue lesions, both acute and chronic, continue to be referred to physiotherapists for treatment to assist healing and reduce residual loss of function. A review of the literature suggests that shortwave diathermy, ultrasound and laser are the three electrophysical treatment modalities that are currently in common usage for the treatment of such injuries (Kitchen and Partridge, 1990; 1991; 1992).

Clinical efficacy is ultimately dependent on the relationship between the agent, the injured tissues and the therapist administering the treatment. Despite the regular clinical use of electrotherapy since the beginning of the century, few researchers reported studies evaluating their biological effects and clinical efficacy prior to the early nineteen seventies. Since then there has been a gradual increase in the number of studies aiming to achieve these objectives, and the last decade has seen a substantial increase in the number and quality of these. Despite this, knowledge about many modalities is severely limited and information sometimes contradictory.

A major factor influencing the outcome of the use of electrophysical agents is the therapist. As clinicians continue to use electrophysical agents in the treatment of soft tissue injuries, it is their task to evaluate the individual patient and select the most appropriate treatment package. Little is known, however, about which agents are being selected by the clinicians, the factors affecting selection or the processes leading to the choices made.

A number of previous studies have briefly examined the general usage made by therapists of a number of types of equipment (DWH, 1980a,b; ter Haar et al, 1987; Robinson and Snyder-Mackler, 1988; Lindsey et al, 1990; Baxter et al, 1991). Studies have examined the levels of equipment held by clinical departments (Ide and Partridge, 1986), the types of equipment discarded and bought (Ide and Partridge, 1989) and the frequency of usage and the academic backgrounds of therapists using the equipment (Robinson and Snyder-Mackler, 1988; Lindsey et al, 1990). ter Haar et al (1987) and Baxter et al (1991) also collected information about the types of conditions being treated with ultrasound and laser respectively. Few studies, however, examine the use made by clinicians of more than a single type of agent and the relationship between the condition under consideration and selection of treatment.

Clinicians must 'problem solve' in order to select treatments. Such problem solving, especially under conditions of such uncertainty, is a complex process. Kassirer et al (1982) and Higgs (1992) emphasise the need for the clinician to have both a substantial store of medical knowledge and the necessary reasoning skills to apply that knowledge to the given patient. The process is beset with difficulties owing to the volume of information with which the clinician has to contend, the inherent difficulties associated with remembering and manipulating such volumes of knowledge in clinical practice (Eddy, 1984) and the difficulties associated with uncertainty, fuelled by the sparse and disparate information about each agent (Eddy, 1984; Katz, 1984).

A number of researchers have attempted to examine the interface between the therapist, the agent and the patient, with the intention of being able to predict future events, find the causes of observed events and determine appropriate actions to cause changes (Rasmussen, 1983). Rouse and Morris (1986) draw out three fundamental themes underpinning such work, which are describing, explaining and predicting. Problem solving models have been studied in relation to a variety of processes including manual performance (Kessel and Wickens, 1982), mathematical problem and puzzle solving (van Bussel, 1980; van Heusden, 1980) and chess (Charness, 1981; 1989). In addition, problem solving in clinical practice has been investigated (Elstein et al, 1978; Payton, 1985; Moskowitz et al, 1988).

Studies have examined ways in which assistance can be offered to clinicians to augment their problem solving skills or ways in which the skills of both inexperienced clinicians and students can be enhanced (Pauker et al, 1976; Shortliffe, 1976; de Dombal, 1984). Fox (1984) and Kassirer et al (1982) both suggest that at present those lacking experience are expected to absorb 'by osmosis' (Fox, 1984) the skills necessary to select treatments, and Kassirer et al (1982) note the benefits associated with teaching the problem solving methods used by experts in clinical reasoning. Such reasoning methods must first, however, be described to provide an appropriate model of problem solving.

This study examines the interface between the agent and the therapist. In this thesis the nature, use and selection of three forms of electrophysical treatments used by practising clinicians in the management of soft tissue lesions will be examined, these agents being ultrasound, shortwave diathermy and laser.

First, the knowledge available about these agents will be examined to identify what is presently known about each and to highlight deficiencies in information. Second, current, reported usage of ultrasound, shortwave diathermy and laser in the management of soft tissue lesions by physical therapists in England will be examined. The types of lesions treated, the adjunct and combined usage of each agent and the sources of information used to inform practice will be evaluated. Finally, the problem solving strategies used by expert clinicians to select electrophysical treatment for subjects with soft tissue lesions will be investigated.

The aims of the project are therefore to:

1. provide a critical review of reported work which examines the physical and physiological effects, and clinical efficacy of shortwave diathermy, ultrasound and laser in soft tissue healing.

2. examine the current clinical usage of ultrasound, shortwave diathermy and laser to aid soft tissue healing.

3. investigate the problem solving strategies used by expert physiotherapists in the selection of electrophysical treatments for soft

tissue lesions.

This work will facilitate the future development of pedagogical tools which can be used to assist student physiotherapists in learning to select electrophysical treatment agents. It will also provide information which can be used by expert systems to codify and emulate the clinical problem solving and decision making processes of expert clinicians in the treatment of soft tissue lesions and so assist clinical practise.

The study is divided into three sections, each of which addresses one of the above aims. Section I reviews the literature about the physical properties of each agent, their interactions with tissues and their clinical efficacy. Section II examines current clinical use of the three agents by a randomly selected sample of physiotherapists in England through the use of a survey. In Section III, the problem solving strategies used by experienced physiotherapists as they develop a plan of treatment for patients with soft tissue lesions is examined.

SECTION I

KNOWLEDGE BASE UNDERPINNING THE USE OF ELECTROPHYSICAL AGENTS IN SOFT TISSUE HEALING

SECTION I: PREFACE

The use and selection of electrophysical agents for the treatment of soft tissue lesions is dependent on, firstly, knowledge of the agents in question and the processes underlying the repair of soft tissue injuries and, secondly, skill in clinical problem solving (Kassirer et al, 1982; Higgs, 1992). In addition, evaluation of practice must be conducted on the basis of a clear understanding of the nature of the agents.

Prior to investigating the use made by physiotherapists of ultrasound, shortwave diathermy and laser and the problem solving techniques they employ when selecting treatments, Section I of this thesis will therefore review the relevant information which is currently available about each agent and briefly discuss the healing processes which occur following soft tissue damage.

Section I consists of six chapters; the first is a history of the development and use of each agent in question. Chapters two and three review the physical characteristics of each modality and the ways in which they interact with biological materials. Chapter four discusses briefly the processes involved in soft tissue healing. The final two chapters discuss evidence of the physiological effects mediated by each agent and the literature which addresses their clinical efficacy.

Section I, chapter 1.

ULTRASOUND, SHORTWAVE DIATHERMY AND LASER: A HISTORICAL PERSPECTIVE

This thesis focuses its attention on the selection and use of ultrasound, shortwave diathermy and laser in physiotherapy practice. In order to provide an understanding of the context in which recent developments have occurred, the history of the development of these agents over the last century will briefly be examined.

Ultrasound

Ultrasound is a form of vibrational energy, having a frequency above the limit of human hearing (20 kHz). It has found many uses over the past fifty years in a wide variety of fields, including the manufacturing industry, the military services and medicine. Examples of its use include the detection of objects, the detection of defects in structures such as roads and bridges, taking depth soundings at sea, food processing and industrial cleaning. In the field of medicine it has been used as a diagnostic tool, a hyperthermic tool in cancer treatments, a surgical instrument and, in physiotherapy applications, a tool to aid tissue healing (Hill and ter Haar, 1989; Dyson, 1990).

In about 1880, Pierre and Jacques Currie noted that placing a quartz

crystal in an alternating electrical field resulted in the emission of sound waves (Fyfe and Bullock, 1985). This information lay relatively dormant until the beginning of the Great War, when Langevin, a physicist who knew of the work of the Curries, began to examine the possible use of sound waves to detect submarines. Wood, a biologist, visited Langevin in 1917 and noted that the beam could kill small fish. After the end of the war, Wood and a colleague, Loomis, began to work with sound waves, examining their biophysical effects; they confirmed that cell death could be induced by the use of ultrasound and that small fish, frogs,
and paramecium be killed if they passed through the beam. Spirogyra were torn apart but bacteria survived (Wood and Loomis, 1927). They postulated that heating might be the cause of death.

Further work over the years led to the present day medical uses of ultrasound including its hyperthermic, surgical, tissue imaging and therapeutic applications. Ultrasonic hyperthermia has been shown to be a useful adjunct to cancer therapies (Kremkau, 1979; Corry et al, 1984), whilst the surgical use of ultrasound can involve the use of sound to enhance the efficacy of a surgical instrument or to replace the instrument (Wells, 1985). Sound may also be used in the disintegration of renal calculi (El Fahiq and Wallace, 1978; Saunders and Coleman, 1986). Tissue imaging was first developed during the 1940s, and new and better techniques continue to be investigated and examined (Duck et al, 1985; NCRP report No 86, 1986). Sound has been used in the imaging and possible diagnosis of conditions affecting the heart, the vasculature, eye disease, gynaecological problems, obstetrics (Hill and ter Haar, 1989) and the structure of the skin (Karim et al, 1994). The most pressing issue presently facing researchers in this area is the safety of scanning tissues with such a modality, especially within the area of neonatal development (Stewart, 1983; Duck et al, 1985; NCRP report No 86, 1986).

Stanley (1958) noted that there were anecdotal reports of the use of ultrasound in physical therapy practice in Germany in the early 1930s, whilst Herrick (1949) and Nelson et al (1950) reported its use to treat sciatica, eczema, osteosclerosis and cancers. The proliferation of clinical ultrasonic units, available in the 1950s, encouraged the wide spread use of insonation in clinical practice despite most early research into the actions of ultrasound having focused on the destructive properties of the medium rather than its therapeutic values (Fyfe and Bullock, 1985). The result was that much early treatment was said to be unsoundly based and occasionally even dangerous (Herrick, 1949; Nelson et al, 1950; Buchtala, 1952; Miller and Weaver, 1954; Schwartz, 1957). Despite this increase in use over the years, research into the effects of ultrasound in living tissues at the dosages used in physical therapy practice was not commenced until about 1968 (Fyfe and Bullock, 1985).

Ultrasound is thought to have two possible modes of action, thermal and nonthermal (NCRP report NO 86, 1986; ter Haar, 1987; Miller, 1987). The result has been the development of two schools of thought concerning usage. Tomm (1953) noted that those on the west of the Atlantic held the

were
view that thermal effects primarily responsible for any biophysical changes that occurred, whilst those in Europe tended toward the view that lower doses should be used and that effects were primarily mediated through neural stimulation. Lehmann and his fellow workers, in North America, represented those who believed that the thermal effects were most important. They were interested in the heating effects of shortwave and microwave diathermies and they expanded their interest into the heating effects of ultrasound. Evidence showed that heating was indeed produced (Lehmann et al 1966; 1968). The dosages required, however, were high; subjects were required to tolerate a level of insonation determined by the point at which pain was reported. Such intensities were found by some workers to be damaging to the tissues (de Forest et al, 1953; Bender et al, 1954; Payton et al, 1975). Others, however, reported that biological effects could result from low intensities of sound; Miller and Weaver (1954) noted changes in circulation and Williams (1968) reported improved healing in chronic ulcers following the use of much lower dosages.

More recent studies have emphasised the role of ultrasound to assist soft tissue healing rather than to heat joint structures or to affect neural transmission (Fyfe and Bullock, 1985). This emphasis was first highlighted by Soren (1965) and Patrick (1978). Experimental evidence for its efficacy in the resolution of soft tissue damage has been provided by workers such as Dyson and colleagues (1982; 1986), Harvey et al (1975), Fyfe and Chahl (1984, 1985) and Young and Dyson (1990b; 1990c).

Currently, work is being directed at examining the fundamental effects ultrasound can have on cells and tissue both *in vitro* and *in vivo*, and clinical trials are attempting to evaluate the efficacy of the modality for a number of conditions using a variety of treatment parameters; further details of such work are presented in the following chapters.

Shortwave diathermy

The scientific examination of the effects of different types of diathermy played a major role in shaping the early research on electromagnetic fields and in providing an understanding of their biological effects on human subjects (NCRP report No 86, 1986). High frequency currents were one of those agents examined, and the past century has seen a gradual increase in the use of these currents to produce heating in tissues, with shortwave diathermy (SWD) appearing as a specific therapeutic entity during the nineteen thirties (Licht, 1965).

Some of the earliest work examining the use of electromagnetic fields to heat normal human tissue in live subjects was conducted by d'Arsonval in 1892; he reported that currents at a frequency of 10 kHz or more produced a sensation of warmth in tissues without apparently causing any damage or leading to muscle contraction. A number of uses for this form of current were suggested, including the destruction of cancerous tissues and cautery (Licht, 1965). Subsequently, high frequency currents of between 0.5 and 3.0 MHz were used for a variety of therapeutic purposes around the turn of the century

(Licht, 1965). By 1928 radiation of a frequency nearing 100 MHz was being used in clinical practice to heat the tissues; this radiation was an early form of shortwave diathermy (Licht, 1965).

Much early work was orientated towards the use of diathermy as a destructive agent in the treatment of cancers. De Keating-Hart (1909) advocated the use of a combination of high frequency electrical current and ionising radiation in the management of cancers. Others suggested the combined use of diathermy and X-radiations (Hill, 1934) or even diathermy alone (Mortimer and Osborne, 1935). Interest was maintained, though at a low level, in the use of shortwave diathermy for the treatment of cancers as late as the 1970s (le Veen et al, 1976; Kim et al, 1978; Overgaard, 1978). However, despite evidence of moderate success, the method of treatment was never widely adopted in clinical practice.

Use of shortwave diathermy for non-destructive therapeutic purposes has been reported in the literature from the mid 1930s. Pelvic inflammatory disease, prolapsed intervertebral disc lesions and sinusitis were amongst the conditions most commonly reported to benefit from the application of this form of energy (Bengston, 1943; Upton and Benson, 1943; Jahier and Tiller, 1947; Bierman and Licht, 1952; Kottle, 1955).

During the 1930s and 1940s it was suggested that shorter wavelengths, such as those of microwave diathermy, might also be used in the treatment of cancers and soft tissue lesions. Due to developments in technology during World War II, information became available which allowed work on the clinical application of microwaves to be initiated at the Mayo clinic in 1946 (Krusen et al, 1947; Leden et al, 1947). This work led to comparisons between shortwave and microwave diathermy (Siems et al, 1948; Richardson et al, 1950) and a subsequent increased knowledge of the effects of shortwave diathermy on the physiological behaviour of the body tissues, which are discussed in further detail later in this section.

Over the years it has been suggested that radio frequency electromagnetic (RFEM) fields may produce both thermal and nonthermal biological effects in tissues (Nagelschmidt, 1940; Licht, 1965; NCRP Report: 86, 1986; Adey, 1988; Lehmann, 1990; Tsong, 1990). Thermal effects have been clearly documented and have given rise to little controversy (NCRP report No 86, 1986; Lehmann, 1990; Kitchen and Partridge, 1992); however, argument for and against the existence of nonthermal effects rapidly arose (NCRP report No 86, 1986) and have continued into recent debate (Plethig, 1979; Adey, 1988; Anthony, 1988; Collis and Segal, 1988; Tsong, 1990). A number of workers suggest that all effects are thermally mediated, all be it at microthermal levels (Lehmann, 1990), whilst others believe additional mechanisms to be active (Audiat, 1932; Nagelschmidt, 1940; Collis and Segal, 1988; Tsong, 1990).

The issue of wavelength specific effects appeared early, with some workers, including Reiter (1932), suggesting that the therapeutic benefits seen in the treatment of cancers might be wavelength specific. More recently, Adey (1980) has suggested that power windowing may have a major influence over the response of tissue to weak electromagnetic fields. This debate extended into the area of thermal changes induced in tissue. During the first decade of the development and use of shortwave diathermy, most research consisted of measuring the temperatures arising in the superficial and deep tissues of both animal and human subjects exposed to both capacitive and inductive type applicators (Lehmann, 1990). The treatment parameters described were frequently limited to a statement of the power level of the source and the temperature developed in the tissues. It was noted that similar power outputs do not necessarily result in the same heating patterns and some researchers, including Pflomm (1931) and Hill and Taylor (1936), concluded that the variations in temperature achieved were due to wavelength variation. Others, such as Mittleman et al (1941), believed the variation to be mainly due to differences in electrode configuration and spacing and the rate of energy absorption.

The NCRP report No 86 (1986) suggests that much of the early controversy over both this issue and the thermal/nonthermal issue was fuelled by a lack of precision in experimental work leading to contradictory results; poor quantification of the level of energy absorbed by the tissues is suggested to be the primary cause of this problem. The writers of this report note that 'because the extent of heating of tissues seemed to vary with the frequency, even with the same apparent output power of the various devices, many researchers jumped to the conclusion that there are selective therapeutic properties associated with wavelengths'.

Most early reports centre around the use of continuous shortwave diathermy. Pulsing of diathermy agents was, however, introduced in North America in the late 1930s and early 1940s by Ginsberg and Milanowski (Hayne, 1984). The Diapulse apparatus was subsequently developed and tested (Ross, 1981). Pulsed shortwave diathermy, in the form of Diapulse, was introduced into Britain in the early 1970s, following observation of its use for sports injuries in American participants at the Mexico Olympics in 1968.

Both continuous and pulsed shortwave diathermy have been used in the treatment of pain and soft tissue lesions over many years and there has been a gradual increase in the study of the physical behaviour, physiological effects and efficacy of both. This information will be examined in more detail in the following chapters.

Laser

Light amplification by stimulated emission of radiation, or 'laser', describes an intense, coherent, monochromatic directional light beam, or optical radiation, and as such is part of the electromagnetic spectrum (Goldman et al, 1989).

The early 1950s saw the development of the MASER (microwave amplification by simulated emission of radiation) at Columbia University (Gordon et al, 1955). Some years later Schawlow and Townes (1958) proposed that an optical maser should be developed and subsequently began the development of the laser. Schawlow (1991) describes how, in association with Charles Townes, he began the process of developing laser generators in 1957, and, 1958 and in 1960, Maiman, based at the Hughes Laboratories in Malibu, published the first account of the production of laser radiation using a ruby crystal. By 1960 five different substances had been identified which were found to give rise to laser light. Work rapidly progressed from this point, with other scientists becoming involved in the search and an increasing number of substances were identified, each of which emitted laser light of differing frequencies.

Since then laser has been used for many purposes; examples of use include precision measurement, depth sounding and identification of objects or flaws, communication, radar and guidance systems, welding, drilling and cutting, food processing, photography and holography (Goldman et al, 1989). In addition laser is used in medical practice; medical use of laser may be divided into high reactive level laser treatments and low level laser therapy. High reactive-level laser treatment (HLLT) was initially used in ophthalmology and dermatology as an agent of destruction and as a surgical instrument (Goldman et al, 1989); its use in surgical procedures later spread to most branches of medicine (Ohshiro, 1991). It is currently used extensively for scale removal and bridge work in dentistry and is used in a number of branches of medicine in diagnostic procedures (Goldman et al, 1989).

Low level laser therapy (LLLT; a term coined by Ohshiro and Calderhead, 1988) utilises very low intensities of irradiation and claims to employ the nonthermal photobiological properties of the agent to produce therapeutic effects (Ohshiro and Calderhead, 1988). Low-energy laser therapy has been investigated and used in clinical practice for over twenty five years (Basford, 1986, 1989; King, 1989). The initial work began in Eastern Europe in the sixties (Mester et al, 1967; Mester et al, 1971; Mester, 1975) and in Canada with Plog reporting work in the field of laser acupuncture as early as 1973 (Plog, 1980). However, much of this early work lacked credibility owing to, first, the minimal reporting of methodological detail and, second, the number of unsubstantiated claims made during this period (Basford, 1986, 1989; King, 1989).

The late 1980s have seen a substantial increase in interest in low level laser therapy by both scientists and clinicians. By 1990, at the first meeting of the International Laser Therapy Association, eleven countries were able to report an interest in low level laser therapy for therapeutic purposes; these included both American continents, Europe (including the former USSR, France and Britain) and China, Japan, and Korea. The USSR, Japan and China made the greatest use of the modality; most other countries noted an increasing interest in its use but emphasised that clear evidence of clinical efficacy was still lacking. This lack was highlighted by Enwemeka (1991) of the USA, who reported that approval for the use of laser in clinical treatment in America had not as yet been granted by the Federal Administration Board (USA) and Goepel of France (1991) who reported that the initial interest in laser displayed in his country had diminished as the lack of evidence for its efficacy became apparent. By the following laser conference in 1992, a increased interest was being shown in the subject with a greater number of papers addressing the clinical and scientific issues underpinning the use of low level laser therapy in clinical practice.

Both continuous and pulsed laser therapy have increasingly been used in the treatment of pain and soft tissue lesions over the last few years and there has been a gradual increase in the study of the physical behaviour, physiological effects and efficacy of both. This information will be examined in more detail in the following chapters.

Conclusion

Ultrasound, shortwave diathermy and laser have passed through a variety of developments over the past century. All are in current clinical use in the Britain and abroad but the following chapters will demonstrate that all three suffer from a paucity of evidence to support their claims for clinical efficacy. Many of the controversies surrounding each agents throughout their history will be found to affect the most recent discussions about the mechanisms of interaction and clinical effects of each agent. In the following chapters, the current knowledge available to the therapist about the properties, behaviour, biological effects and clinical efficacy of these three modalities will be examined.

Section I, chapter 2.

PHYSICAL PRINCIPLES: ULTRASOUND, SHORTWAVE DIATHERMY AND LASER

Ultrasound, shortwave diathermy and laser are all forms of electrophysical agent used by physiotherapists in the management of soft tissue lesions; they differ, however, in their physical characteristics. Ultrasound is a mechanical energy whereas shortwave diathermy and laser are both electromagnetic radiations of differing wavelengths. Their physical properties and consequent behaviour within the body tissues therefore differ to some degree. Each will be described in the following chapter.

Ultrasound

Ultrasound is a form of acoustic energy. It is a mechanical wave requiring an elastic medium through which to travel and takes the form of a sine wave, displaying the parameters of wave length, frequency, amplitude and velocity. Its frequency range occurs above the upper limit of human hearing (about 20 kHz). The frequencies primarily used as therapeutic tools by physiotherapists lie between 0.75 and 3 MHz (Low and Reed, 1990).

The passage of an ultrasound beam through a medium results in fluctuation in the values of a number of physical parameters. These fluctuations are specific to the material and describe the state of that medium; they are the result of periodic excursions of water molecules and particles of other materials which arise as a consequence of the presence of the acoustic wave. Thus 'particular' displacement (s), velocity (v), acceleration (a) and pressure (p) changes occur. As ultrasound takes the form of a sinusoidal wave, maxima and minima values for the s,v,a and p parameters arise (Hill and ter Haar, 1989).

The wavelength of a sound wave (λ) is characterised by the medium through which it travels; such waves are defined by the speed of sound as it travels away from its source and the frequency of the vibration induced. Thus $\lambda = c/f$, where c is the speed characteristic and f the frequency of the vibration. The propagation speed for most human soft tissue is in the region of 1500 m/s, with an induced frequency of 1 MHz resulting in a wavelength of 1.5 mm (Hill and ter Haar, 1989).

The passage of ultrasound waves depend on the characteristic acoustic impedance (z) of that material, which for therapeutic purposes is body tissue (Ward, 1986; Hill and ter Haar, 1989; Frizzell and Dunn, 1990). Z is defined as the product of ρ c, where ρ is the density of the medium and c the speed of sound in that medium (Hill and ter Haar, 1989).

The intensity of a sound wave is defined as 'the time average of the rate of propagation of energy through a unit area normal to the direction of the propagation' (Frizzell and Dunn, 1990). Intensity is expressed in watts per centimetre squared (W/cm^2).

As the ultrasound beam passes through tissue, the pressure, p, of the sound wave is reduced. This process is termed attenuation. The loss of pressure is related to the initial pressure amplitude of the wave and the attenuating co-efficient, α , of the medium, and thus differs for each tissue type (Allen and Battye, 1978; Hill and ter Haar, 1989).

In human tissues a substantial part of the process of attenuation is due to conversion of the mechanical energy to heat energy; this is often referred to as absorption. The coefficient of absorption describes the heat generated in tissues by the passage of ultrasound (Hill and ter Haar, 1989). Attenuation also results from scattering of the beam due to interaction with the interfaces of structures which are small compared with the wavelength of the ultrasound (Frizzell and Dunn, 1990).

Attenuation accounts for two phenomenon seen in the tissues following the application of a ultrasound beam; firstly, it results, at least in part, in the transfer of energy to the tissue in the form of heat. Secondly, attenuation of the ultrasound beam by specific tissues will affect the extent to which that beam will be able to penetrate to deeper regions. There is a slow increase in the rate of absorption with an increase in wave frequency, the higher the frequency the more efficient the absorption and therefore the more superficial the penetration (Docker, 1987). Scattering of incident energy out of the region of interest will also result in a reduction of energy with an increase in tissue depth (ter Haar, 1987).

This reduction in wave energy decreases exponentially (Ward 1986); Ward (1986) and Dyson (1985) provide details of half value depths for a number of tissue types, which vary from 2 mm (tendon) to 16 mm (fatty tissue) at 3 MHz. Attenuation increases with an increase in frequency; however, in human tissue this relationship is approximately 1 and thus attenuation is approximately proportional to frequency (Hill and ter Haar, 1989). The attenuation of ultrasound in human soft tissue is high, thus facilitating its therapeutic effects.

Ultrasound beams are subject to reflection, refraction and defraction both at tissue boundaries and within the tissues. Reflection occurs on dissimilar materials; it occurs when an acoustic beam is directed at the human body, particularly high values occurring at the boundary between air and skin and at the junction between the periosteum and bone. Williams (1987) and Hoogland (1989) list measured levels of reflection occurring at a number of tissue interfaces. Both authors note the very high level of reflection which occurs at the air-tissue interface (99.9% and 100% respectively) in the absence of a coupling medium and the relatively high level of reflection occurring at the soft tissue-bone interface (15-40% and 34.5% respectively).

Refraction, which results in an alteration in the path of an acoustic beam, occurs as the acoustic beam passes across the boundary from one material to another; the greater the difference in the characteristic impedance of the two tissues the greater will be the angle of refraction. The scattering which results from this process contributes an element to the attenuation of the acoustic beam as it passes through the tissue. The more homogenous the tissue the less scattering will occur; thus under these conditions most attenuation will be the result of absorption and consequently result in tissue heating (Lyons and Parker, 1988). In addition diffraction results in further scattering of the wave as it passes through the tissues; the effect occurs repeatedly with the result that the sound beam is further scattered though the tissues (Lehmann, 1990). Reflection, refraction and defraction thus result in a complex wave pattern within human tissues.

The form of the acoustic field generated by a source is dependent on four factors; these are the dimensions of the radiator, the shape of the radiator, the displacement amplitude distribution over the surface of the radiator and the acoustic absorption coefficient of the medium (Frizzell and Dunn, 1990). Two types of idealised ultrasonic field exist; these are the travelling wave linear disturbances, or plane waves, and the stationary field (Hill and ter Haar, 1989; Frizzell and Dunn, 1990). The first is of greatest interest in therapeutic ultrasound, though the therapeutic beam generated for use in clinical practice is an approximation to it owing to the variables previously mentioned.

The discussion thus far has assumed the passage of a plane wave. Plane waves are sinusoidal in nature, showing variations in the parameters of displacement, velocity, acceleration and pressure. A standing field normally only occurs when a continuous sound wave is passed into a confined space and strikes the boundary material, which is of a significantly differing impedance, at a right angle. Reflection results in the two beams being superimposed on and in phase with one another. Such a wave is characterised by a spatial pattern of 'nodes' and 'antinodes' and by a zero net time averaged flux of energy across any surface within the field of energy (Hill and ter Haar, 1989).

Therapeutic transducers emit a cylindrical beam of ultrasound which is approximately the diameter of the transducer (Williams 1987, Hoogland 1989), and such a beam may be divided into two main parts. These are the near field or Fresnel region, and the far field, or Fraunhofer region; a transitional region links the two. Therapists make use of the near field of the beam which is highly non uniform in terms of pressure and intensity, the four parameters (s, v, a, p) interrelating in a complex fashion (Williams, 1987; Hill and ter Haar, 1989; Frizzell and Dunn, 1990). There can be considerable swings in amplitude between the maxima and minima of these parameters and a lack of uniformity in the field.

Measurement of sound fields

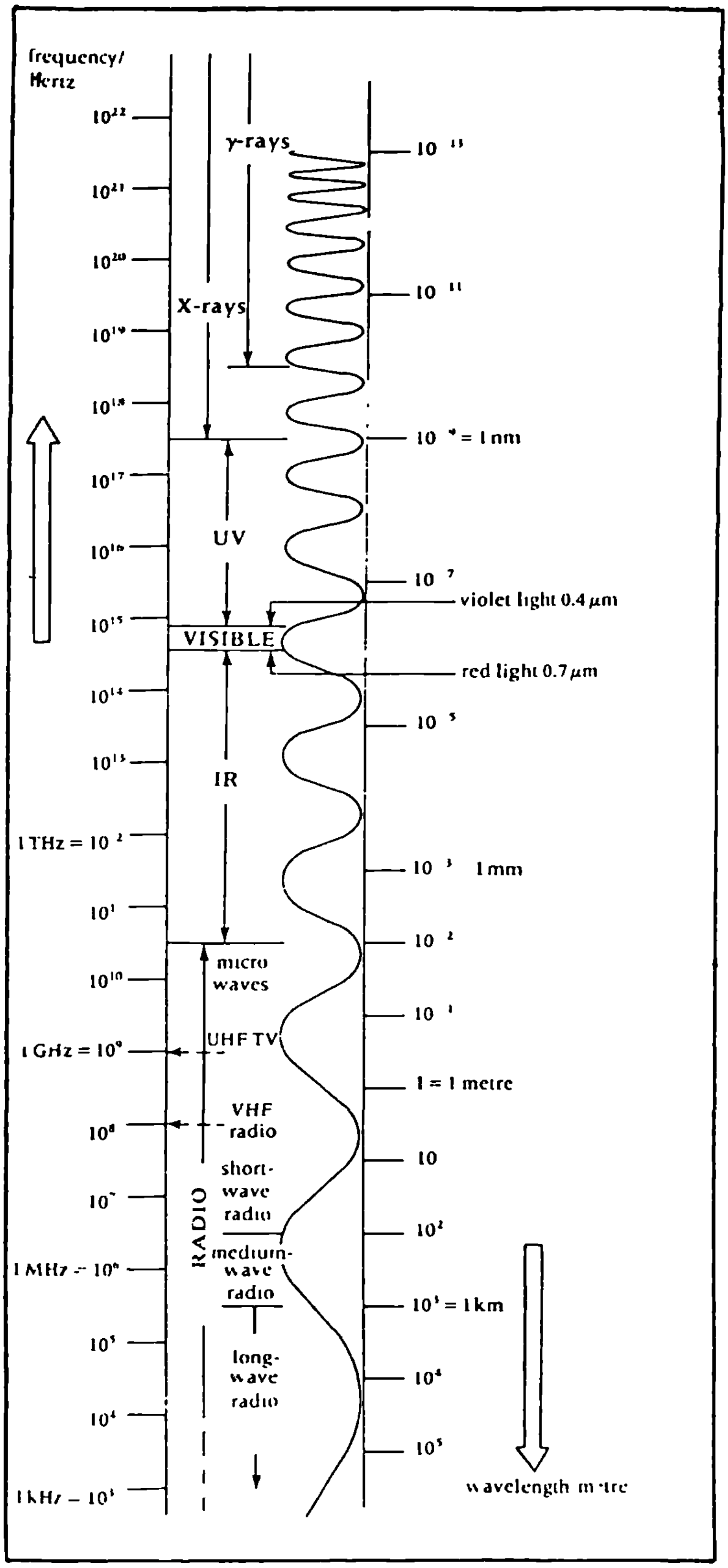
It is essential that in all studies examining the effects of ultrasound on tissues the characteristics of the sound field employed should be described fully and accurately in order to facilitate comparison of studies and inform the ongoing debate about this treatment agent. Hill and ter Haar (1989) note that at present there is not complete agreement about the mechanisms which may produce biological effects in the human body, and for that reason as much information as possible should be noted.

The parameters to be considered when reporting the application of therapeutic ultrasound dosage include frequency, area of insonation, power P, intensity I (spatial average SA, temporal average TA, spatial peak SP, temporal peak TP), mark/space ratio (duty cycle), time of irradiation and the beam nonuniformity ratio. Particular care should be taken to ensure that measuring devices are calibrated and that the calibration refers to a generally agreed standard.

Shortwave diathermy

Shortwave electromagnetic radiations range in frequency from 10 to 100 MHz; known as radio frequency waves, the shortest wave band is used in therapeutic diathermy. Short radio waves lie between microwaves and medium radio waves on the electromagnetic spectrum, as shown in figure 1 overleaf. Those most commonly used by therapists to heat or treat tissue are of the frequency of 27.12 MHz (Delpizzo and Joyner, 1987; Low and Reed, 1990) and are commonly termed shortwave diathermy (SWD). Shortwave energy can be delivered in either a continuous or pulsed mode. Whilst continuous shortwave diathermy may be confined to a frequency of 27.12 MHz, pulsing results in the development of side bands which can

Figure 1. Electromagnetic spectrum



mean that the energy used ranges in frequency from 26.95 to 27.28 MHz, with little if any of the energy being of the parent band.

Radio waves have the longest wavelength of any region of the electromagnetic spectrum and therefore the shortest frequency; they thus have the lowest energy per quantum (Gibbs, 1990). They are produced as the result of electrical oscillations and both electric and magnetic fields may be set up as a result of their action.

An electric field (E) is set up as the result of the presence of electrical charges; this field is characterised by both direction and magnitude. An electrical charge, such as an electron or proton, placed within this field will experience a force (F). E and F are related as follows:

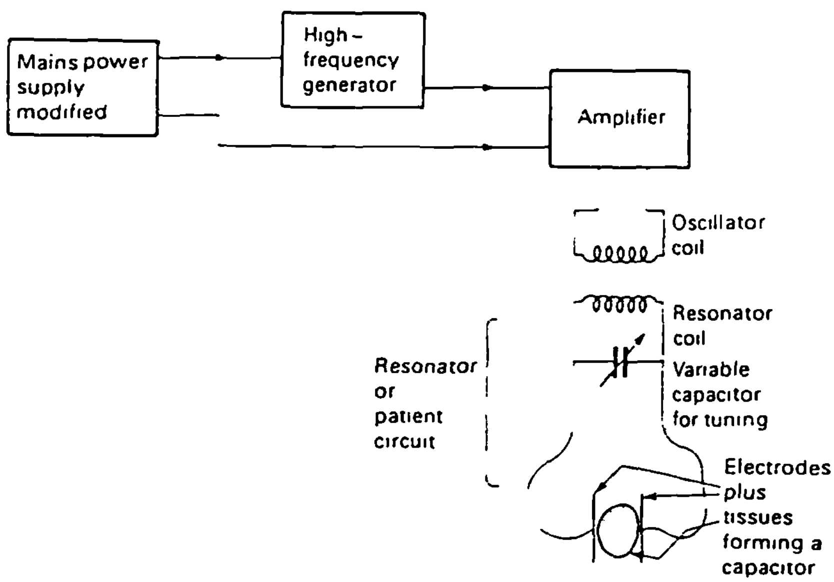
$$F = qE \qquad (q = \text{size of charge placed in the field})$$

In electrically conductive materials, such as living tissues, the forces will result in the production of electrical currents (Anderson and Kaune, 1989).

A magnetic field is produced by electrical charge **in physical motion** (Anderson and Kaune, 1989). Magnetic fields may also exert forces on other charges which are in motion. Thus an alternating electrical current may initiate the production of a magnetic field and a magnetic field may result in the production of a current, when motion is present. Magnetic fields are specified by two quantities; these are magnetic flux density (B) and magnetic field strength (H), having the units of tesla (T) and amperes per meter (amps/m) respectively.

Both electrical and magnetic fields can be set up in human tissues which are subjected to shortwave diathermy (Delpizzo and Joiner, 1987; Guy, 1990). In the application of this agent the patient is made part of the electrical circuit by the use of a inductive coil or capacitive type electrodes; this is shown in figure 2. The resonator or patient circuit and generator circuit are tuned by use of variable capacitor in order to match parameters of each circuit and thus generate maximum power transfer.

Figure 2. Block diagram to show shortwave diathermy generation



The interaction of the field with the tissues is affected by the macroscopic property of the tissue called 'complex permittivity'; this represents the dielectric constant and the loss factor of the tissue (Delpizzo and Joiner, 1987). Complex permittivity is a function of frequency and therefore the propagation and attenuation of the electromagnetic waves are dependent on frequency (Johnson and Guy, 1972).

The use of a capacitive circuit to treat a structure results in the tissue lying within an oscillating electrical field; this causes vibration of tissue molecules and thus heating of tissues. The tissue acts as a dielectric and the level of heating is thus partially dependent on the dielectric constant of that structure (Guy, 1990). Such a high frequency alternating voltage applied to tissues gives rise to two types of current:

1. A conduction current (I_R)

Heat develops in relation to the following equation:

$$Q = I_{R2.}\ R.\ t$$

where Q = heat in joules

I_R = the intensity of the current in amperes

R = ohmic resistance

t = time

2. A displacement current (I_C)

A displacement of electrical energy occurs as the result of polarisation of the tissue; the magnitude depends on capacitance of the tissue and the frequency of the alternating current.

The use of an inductive applicator results in the tissue being placed within a rapidly alternating magnetic field which is generated by passing the high frequency current through a coil; this results in the setting up of eddy currents within the tissue, induced by the oscillating electromagnetic field.

The level of heat generated depends on the conductivity of the tissues, those rich in water and ions being heated most readily. Heat is generated according to the following equation:

$$Q = I^2 . R . t$$

where Q = heat in joules

I = current

R = ohmic resistance

t = time

It has been suggested by a number of workers that pulsing electromagnetic energy of very low intensities may give rise to effects other than heating (Pilla, 1974; Adey, 1988; Tsong; 1990); these will be describe further in chapter 3.

Measurement of shortwave diathermy

Measurement of dosages of shortwave diathermy have traditionally relied on the thermal sensitivity of the subject, thermal comfort determining the dosage given (Low and Reed, 1990; Michlovitz, 1990). However the National Council on Radiation Protection and Measurements recommends the use of a quantity termed the 'specific absorption rate' (SAR) to quantify the rate of energy absorption in tissues exposed to electromagnetic fields (NCRP report 67, 1981). The SAR is given in units of watts per kilogram (W/kg).

The parameters used to describe shortwave diathermy should include frequency, power, time of irradiation and method of application for continuous wave therapy; the type of field used should also be indicated. Peak power, average power, pulse length, and rest period or number of pulses per second should be added for pulsed therapy.

Laser

Laser is an acronym for light amplification by stimulated emission of radiation. Light is a form of electromagnetic energy and its position on the spectrum is shown in figure 1. The wavelength of light, or optical radiations, ranges from 1 nanometre (nm) to 1 millimetre (mm) and include not only the visible portion of the spectrum but also the adjacent parts of the infrared and ultraviolet regions (Goldman et al, 1989). However, the boundaries of this 'region' are to some degree arbitrary. That part of the spectrum most commonly used in the practice of low level laser therapy (LLLT) displays a wavelength of between 630 nm to 1300 nm (Department of Health and Social Security, 1984). It includes both visible light and the near part of the infrared spectrum.

The production of laser light is described by Calderhead (1988) and Goldman et al (1989). Energy is applied to the atoms of the lasing medium. This results in the uptake of energy by electrons within the structure, resulting in their temporary transfer to a larger orbital path. This additional energy is rapidly lost, the electron returning to ground energy level and the stored energy is released as a photon of a wavelength, which is specific to the atoms of the lasing material; this process is termed the 'spontaneous emission of readiation' (Calderhead, 1988). Such a photon may cause the release of additional photons from atoms which are in an excited state. Under these conditions all photons released will be of the same wavelength; this process is called 'stimulated emission of radiation'. These two processes result in the production of a laser beam, a beam which is a more potent beam than other unmodified optical radiations (Goldman et al, 1989).

Laser light is defined as monochromatic, coherent and [illegible] (Kleinkort and Foley, 1982). Monochromaticity indicates that the elements of a specific laser beam are all of the same frequency; coherence that the paths followed by each element are in phase, both in terms of time and space, and oll ation indicates that the beam demonstrates little divergence, being almost parallel (Kleinkort and Foley, 1983; Calderhead, 1989). Gibbs (1990) also notes that laser light is produced in an unbroken wave chain. However, some authors such as King (1989) believe that these characteristics may be at least partially destroyed once the beam has passed into the tissue. This effect is attributed to the multiple internal reflections, due to reflection, refraction and defraction of the light, which will occur as a result of the inhomogenicities of the skin and underlying tissues when laser light is applied to the body. Others believe that these characteristics may retain at least some of their integrity; Hode (1992), for example, suggests that the chains of waves may be broken into small segments within the tissues. These segments may be of an adequate length to effect their properties on small tissue units such as cells.

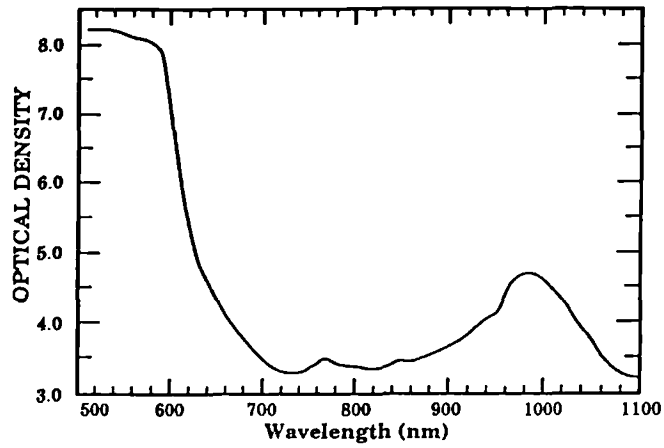
Laser type is determined by the wavelength of the light used, and in turn by the lasing medium ; for example the helium-neon (He-Ne) and gallium arsenide (GaAs) lasers produce fixed wavelength beams of 632.8 nm and 904 nm respectively. Various solids, liquids, gases and diode junctions have been found to produce lasers of defined wavelengths.

Light may be reflected, transmitted, scattered and absorbed both at the surface of the tissue and within it (Kolari, 1985; Ohshiro and Calderhead, 1988; Goldman et al, 1989) and it is these features which provide reason for doubt on the part of some that it is properties specific to laser light that bring about biological changes in tissues (King, 1989). The light beam is attenuated as it passes through the tissues due both to absorption and scattering of the beam, with different tissues attenuating light of different frequencies to differing degrees (Ohshiro and Calderhead, 1988; King, 1989). In addition, wavelength affects the level of attenuation of the beam. For example, Goldman et al (1989) indicate that almost 99% of the radiation penetrating the skin from laser sources in the 300 nm to 1000 nm range will be absorbed in the first 3.6 mm of tissue whereas lasers from the infrared region of the spectrum will penetrate most deeply; those approaching ultraviolet wavelengths will penetrate minimally. Despite the complex nature of light penetration in tissue and the variation in penetration according to the laser wavelength, it is presently agreed that levels of between 1 mm to 4 mm normally occur (Kolari, 1985; King, 1989).

Only light which is absorbed can initiate photochemical processes (Smith, 1991a, b). Different materials absorb light of different frequencies to differing degrees, visible light lasers interacting preferentially with specific, pigmented tissues. Thus blue-green light from the argon laser (476.5 - 514.5 nm) is rapidly absorbed by biological pigments and thus does not therefore penetrate deeply and the carbon dioxide laser (10,600 nm) is almost completely absorbed by water and thus penetrates very short distances. In contrast the red light form the He-Ne laser (632.8 nm) is not absorbed to a great extent by blood and thus the laser penetrates further into the tissue; it is absorbed by cytochromes.

Smith (1991b) examined the absorption spectrum of the palm of the human hand and the results shown in figure 3 below:

Figure 3. The absorption spectrum of the human hand (Smith, 1991b)



It can be seen from this graph that wavelengths of between 500 and 600 nm do not penetrate the tissue well whilst those between 700 nm and 900 nm and, again, at 1100 nm penetrate more effectively.

Measurement of laser beams

As in the case of ultrasound, it is at present unclear which characteristics of the laser beam precipitate biological effects. Thus it is essential that the characteristics of the laser beam directed at the tissue are fully described to facilitate analysis of results and the comparison of studies.

The parameters which describe LLLT are the lasing medium, wavelength, average power, peak power, time, area irradiated and beam mode (or beam profile) and type, which may be either continuous or pulsed (Ohshiro and Calderhead, 1988). The incident dose is measured as either power density, which is defined as 'the incident photon density of the laser beam at the target tissue' (Ohshiro, 1991) or energy density, which is similarly defined but includes the element of time.

$$1. \quad \text{power density} = \frac{\text{output power in watts}}{\text{area of irradiation}}$$

Power density is therefore measured in watts/centimetre squared (W/cm^2). Power density is most easily controlled by altering the spot size of the incident beam.

$$2. \quad \text{energy density} = \frac{\text{output power x irradiation time}}{\text{area of irradiation}}$$

Energy density includes a time element and is therefore measured in joules/ centimetre squared (J/cm^2).

The following chapter will continue this discussion by considering the interaction between these three agents and biological materials.

INTERACTION OF ULTRASOUND, SHORTWAVE DIATHERMY AND LASER WITH BIOLOGICAL MATERIALS

Ultrasound, shortwave diathermy and laser are all claimed to produce thermal and/or non-thermal changes in tissues. The former two are used in clinical practice for both purposes (Low and Reed, 1990; Guy, 1991; Dunn and Frizzell, 1991; Kitchen and Partridge, 1990; 1992) whilst laser is used in physiotherapy practice as a non-thermal agent only (Ohshiro and Calderhead, 1988; Ohshiro, 1991).

The interaction of ultrasound and shortwave diathermy with biological tissues to produce gross thermal changes will first be considered; this will be followed by a review of the thermal mechanisms through which each agent is thought to produce physiological changes in tissue.

THERMAL AGENTS: ULTRASOUND AND SHORTWAVE DIATHERMY

Heating of tissue through the use of both shortwave diathermy and ultrasound is the result of the conversion of either electromagnetic or sonic energy into thermal energy. However the mechanisms whereby heat is generated in the tissue differ between the two and each will therefore be discussed separately in the following sections.

Ultrasound

A number of trials have established that ultrasound produces an increase in tissue temperature (Abramson et al, 1960a; Lehmann et al, 1978; ter Haar and Hopewell, 1982) and it has been demonstrated that thermal effects can be produced at intensities of between 0.5 - 3.0 W/cm^2 SATA (Williams, 1987). Williams (1987) states that it requires 1 W/cm^2 of ultrasound of a frequency of 1 MHz to raise the temperature of most soft tissues by 0.86^{0}C per minute; this is in the absence of heat removal by blood flow or conduction. Instant heating occurs with both pulsed and continuous beam ultrasound (Sandler and Feingold, 1981; MacDonald and Shipster, 1981; Williams, 1987), though the total heat developed over a period will be less when using a pulsed beam due to the rest periods which may allow almost total dissipation of heat between pulses (Ziskin et al, 1990).

The heating effects of ultrasound have been reviewed by a number of authors including Wells (1977), Williams (1983) and Dunn and Frizzell (1990).

Heating of tissue through the use of ultrasound is due to the absorption of sonic energy by the tissues. Ultrasound passes into the tissues from the head of the transducer causing oscillation of molecules and particles due to the alternations in velocity, acceleration and pressure exerted by the sound wave (Hill and ter Haar 1989). The level of heating depends on (1) the intensity of the acoustic wave, (2) the absorption efficient of the material and its consequent thermal conductivity and (3) the frequency of the ultrasound ; the NCRP report No 74 (1982) states that 'when a plane wave of intensity I passes through a medium in which the amplitude absorption co-efficient is α, energy is lost from the wave and converted to heat at the rate of 2 αI per unit volume'. At the same time, heat is dissipated by conduction to adjacent areas and by the flow of blood through the area (Frizzell and Dunn, 1990; Whittingham, 1994). The final temperature achieved within the tissues is thus a balance between these factors.

The intensity of the ultrasound beam, defined as the rate of delivery of energy per unit area of tissue, is fundamental to the temperature developed. The local heat energy production (or the heating power density) and the temperature increase in the tissues are described by the following equations (Whittingham, 1994):

1. Heating power density (Q)

$$Q = 0.23\ \alpha_{ABS} I$$

where α_{ABS} - absorption co-efficient

I - time averaged intensity of ultrasound

2. Temperature increase (T)

$$T = Qt/s\rho$$

where t - time in seconds

s - specific heat

ρ - tissue density

From these equations it can be seen that as the intensity of the sound beam increases so the temperature rise will be greater. There comes a point, however, in vascular tissues such as muscle when the temperature generated is such that the increase in blood flow through the region may reduce the temperature of the tissue to below that required to induce vasodilation (Guy et al, 1974).

The level of heating varies with the acoustic absorption properties of the tissue and maximal in both protein and mineral based tissues. Thus collagen based tissues, such as tendons, ligaments, joint capsules, periosteum and scar tissue, and bone offer great resistance to molecular motion. They allow limited penetration of energy (collagen tissues, between 7 mm and 21 mm; bone, 7 mm) and are preferentially heated (Goss et al, 1980; NCRP report No 74, 1982). Conversely, greatest penetration and therefore least absorption occurs in fatty tissue (penetration level between 55 mm and 165 mm) and, to a lesser extent, in highly vascular tissues such as muscle (penetration depth between 10 mm and 30 mm), resulting in these tissues being heated least by the application of sound (Williams, 1983; Frizzell and Dunn, 1990).

The level of heating generated in the tissue is also dependent on the frequency of the ultrasound used; an increase in the frequency of the wave form results in increased absorption, decreased penetration and therefore increased local heating (Wells, 1977). A specified quantity of ultrasound energy delivered at a frequency of 1 MHz to fat will have a half value depth of 50 mm whereas when delivered to muscle it will have a value of 9 mm and to collagen a value of 6 mm. An identical quantity of sound delivered at 3 MHz will demonstrate half value depths of 16 mm, 3 mm and 2 mm respectively, resulting in decreased penetration but greater heating of all tissue types.

The heating generated by ultrasound is generally n uniform in distribution due to particle velocity gradients and the associated viscous shear effects produced by differences in the absorption efficients of differing tissues, the reflection of sound waves at the tissue boundaries and the occurrence of interference peaks and troughs (Wells, 1977; NCRP report No 74, 1982; Williams, 1987; Frizzell and Dunn, 1990). 'Hot spots' can develop due to boundary layer heating, especially at the periosteal-bone junction. These effects can be minimised by the continual movement of the head of the transducer over the structure during the application of the agent (NCRP report No 74, 1982; Michlovitz, 1990). However, Frizzell and Dunn (1990) believe these effects to be minimal under normal clinical circumstances as the spots are very small in size and heat conduction should render them harmless, a view not supported by others (NCRP report No 74, 1982).

Shortwave diathermy

Electromagnetic waves of the frequency of shortwave diathermy cause heating of tissue through the conversion of electromagnetic energy to thermal energy. Both continuous and pulsed shortwave diathermy generate thermal changes in tissue with the pulsed agent generating instantaneous heating which corresponds with the peak emission of energy (Erdman, 1960; Hansen and Kristensen, 1973; Verrier et al, 1977; Kloth and Ziskin, 1990). The final temperature reached within the tissues through the use of pulsed diathermy depends, however, on the temporal average rather than the temporal peak intensity (NCRP report No 86, 1986; Michlovitz, 1990).

Delpizzo and Joyner (1987) and Guy (1990) describe heat production in the tissues through three mechanisms:

1. The orientation of pre-existing electrical dipoles within the tissues according to the polarity of the energy source; the alternating electrical source will result in a dipole rotation of the elements.

2. Polarisation of atoms and molecules to produce electric ions in the tissue, resulting in their to and fro movement under the influence of the oscillating electrical field.

3. The displacement or 'drift' of electrons as they orbit around their nuclei as a result of the drag produced by the alternating electrical field.

The first two mechanisms involve the generation of friction associated with motion and the last displacement and collision. Heating can only be produced in the presence of internal electrical fields but both the electric and magnetic fields generated by shortwave diathermy are able to produce heating due to the production of eddy fields within the tissue by the oscillating magnetic fields (Delpizzo and Joyner, 1987).

The level of heating generated in the tissues is dependent on (1) the characteristics of the tissue, (2) the characteristics of the energy spectrum and (3) the total average power delivered to the area.

Tissue characteristics are described in terms of the 'complex permittivity' of the material; this property represents the dielectric constant (the depolarisation characteristics of the tissue type) and heat loss factors of the tissue (NCRP report No 86, 1986; Guy, 1990). The dielectric constant is primarily dependent on the water content of tissues; thus bone and fat, tissues with low water contents, have low dielectric constant values whilst muscle, with a high water content, exhibits a high dielectric constant. The former group display high conductivity and allow greater penetration of energy whilst the later displays low conductivity and low penetration. The dielectric properties of tissues are important in determining the distribution of currents and consequent heating patterns within the tissues, the current density and specific absorption rate (SAR) of individual tissue types depending on the electrical conductivity of the tissue. Additionally the dielectric characteristic differences contribute to the reflection and transmission of power at interfaces between different tissue types.

The characteristics of the energy spectrum affect the temperature developed in the tissue as complex permittivity is frequency dependent; the propagation and attenuation of electromagnetic waves is thus also frequency dependent (Schwan, 1970). However, as continuous shortwave diathermy is defined in terms of a frequency of 27.12 MHz for therapeutic purposes, this factor remains constant for all treatments. Pulsed shortwave diathermy, which allows a certain amount of drift from the norm, may be affected by this characteristic to a small degree.

The intensity of the shortwave diathermy delivered to the area affects the temperature rise occurring in the material. The quantity of heat developed is in accordance with the following equation:

$$Q = I_2 . R . t$$

where Q - quantity of heat

I - intensity

R - resistance of the tissue

t - time

The relationship between the rate of absorption of energy, the tissue cooling mechanisms and temperature change is described in the following equation:

$$\frac{d(\Delta T)}{dt} = \frac{0.239 \times 10^{-3}}{c} \times [W_a + W_m - W_c - W_b]$$

where: ΔT - temperature change

c - specific heat of the tissue

W_a - specific absorption rate

W_m - metabolic heating rate

W_c - power dissipated by thermal conduction

W_b - power dissipated by blood flow

(Guy, 1990)

Heating of tissue with shortwave diathermy results in complex patterns of temperature change; patterns of heating produced in various tissues structures were described by Guy (1990) who noted that tissue type, field type and the orientation of the tissues influenced the final temperature derived. The capacitive electrode method of application results in the preferential heating of superficial fat and bone, both tissues having high impedance levels; one study revealed a SAR 17 times greater in fat than in skin and muscle (Guy, 1990). Such heating is the result of time varying electrical fields. Muscle, blood and synovial membrane, all having a high water content, are preferentially heated when inductive applicators are used; fat displays maximum heating levels of approximately 1/3 of that in the muscle. This form of heating is due to the action by eddy currents induced by the alternating magnetic field produced.

NON-THERMAL AGENTS: ULTRASOUND, SHORTWAVE DIATHERMY AND LASER

Much evidence is available to support the view that ultrasound, shortwave diathermy and laser produce thermal effects in tissue; less is generally available to support the thesis that each agent is also able to induce non-thermal effects. Much controversy surrounds this area; Frizzell and Dunn (1990), with respect to ultrasound, state that 'no biological effects (due to stable cavitation) have as yet been demonstrated', Barker and Freestone (1985) state that 'there is no known mechanism of healing' using pulsed shortwave diathermy and the American Federal Drug Administration Board have yet to be convinced of the efficacy of laser therapy (Enwemeka, 1991).

Tsong (1989) suggests that cells communicate both directly through chemical means and indirectly through the influence of electrical, physical and acoustic signals; this subject has been further discussed by investigators such as Schwan (1985); Liboff (1985), Westerhoff et al (1986), Adey (1988) and Frohlich (1988). A number of theories exist to account for effects seen in the laboratory and much controversy still exists; indeed, Tsong (1989) describes the approach of one biochemist to intercellular communication by means other than the direct effect of chemical activity of molecules and ions as 'astrology'.

The following discussion will first address the 'target' points in the tissue which may be influenced by electrophysical intervention and then address the interactive mechanisms of each agent in turn.

Interactive targets

A number of workers have suggested that the different electrophysical agents may induce changes in cells through similar mechanisms, producing physiological changes through activating a number of electrical and biochemical changes (Tsong, 1989; Frohlich, 1988). However, knowledge in this area is a mixture of fact and theory resulting in much discussion of possible mechanisms (Frohlich, 1988). Study has concentrated on the effects of electromagnetic fields on cellular processes, though it is possible that much of this information may be extrapolated to acoustic energy (Tsong, 1989; 1990). A number of potential sites of interaction have been suggested; these include the cell membrane (Fishman, 1985) and a variety of intracellular structures including the cell nucleus (Nicolini, 1985). The first of these is generally thought to be the most likely site of primary interaction (Stulchy, 1990).

Cell membrane: Alberts et al (1989) have described the cell in terms of its electrical structure and function. The cell membrane consists of a bilayered, phospholipid structure surrounding the central core of the cell; this membrane is studded with trans membranous proteins to which may be attached glycolipid arrays. The transmembranous proteins have a number of functions; they may strengthen the membrane, transport substances, such as proteins, sugars, fats and ions, across the membrane, and form specialist receptor sites for proteins, such as hormones and neurotransmitters, and enzymes (Ganong, 1989). The cell membrane possesses a relative negative charge on its internal surface and a positive charge on its external surface; it therefore possess a difference in potential across the membrane, averaging -70 mV, internally (Alberts et al, 1989). Membrane potential is maintained through the passive and active transport of ions across the cell structure; potassium (K^+) ions pass freely across the membrane in both directions due to passive diffusion whilst sodium (Na^+) ions are limited in this respect. A number of 'pumps' provide active transport of ions and other materials across the cell membrane; two major systems include the Na/K^+ pump, which transports Na^+ ions out of the cell, and the calcium, Ca^{2+}, pump, which removes Ca^{2+} ions from the cell. Both are fuelled by energy derived from the hydrolysis of adenosine triphosphate (ATP).

Intracellular structures: Intracellular membranes surround the internal organelles of the cell and exhibit similar electrical characteristics; they therefore exercise critical control over the movement of substances into and out of these structures (Frohlich, 1988; Alberts et al, 1989).
The structure and function of microtubules within the cell has been discussed by Hameroff (1988) and Symmons et al (1989). Electrically speaking, microtubules consist of dimers, which are charged dipole units, their internal ends being negative relative to the periphery. This structure results in the cell having similar properties to electrets (insulators carrying a permanent charge analogous to permanent magnets); these properties include piezo-electric effects and electro-piezo effects. Additionally, dipoles rotate under the influence of oscillating fields, and exhibit preferred resonant frequencies depending on their moment (Frohlich, 1988). Many other structures will also act as dipoles and oscillate in response to changing fields. In addition to dipole rotation, ionic vibration is likely to occur (Frohlich, 1988).

The interaction of electromagnetic fields with the nucleus of the cell has been reviewed by Nicolini (1985) and Frohlich (1988); Hisenkamp (1978) and Takahashi et al (1986) suggest that pulsed magnetic fields may influence DNA synthesis and transcription. Adey (1988), however, suggests that such interactions are more likely to be the result of the presence of secondary messengers such as cyclic adenosine monophosphate (cAMP) and Ca^{2+} ions.

The nature of the energy imparted to the cell is likely to affect the end result; Frohlich (1988) states that ion oscillation and dipole rotation depends on the frequency and amplitude of the field. Enzyme activity depends on the availability of specific charge sites on membrane surfaces which, Frohlich (1988) suggests may be unlocked by the application of electrical signals of an 'appropriate type'. Tsong (1989) states that 'in principle, each class of protein is adapted to respond to an oscillating force field (electrical, sonic or chemical potential) of a defined frequency and strength'.

It is possible that a number of similarities exist between the mechanisms whereby physiological changes are induced by the use of low level ultrasound, shortwave diathermy and laser; however, evidence of both mechanisms of interaction and physiological effects are limited for each modality and each will therefore be considered separately. The following information provides a brief and simplified outline of the mechanisms involved; the processes are considerably more complex than is indicated in this text.

Ultrasound

Studies by Dyson and colleagues (1970; 1978; 1982; 1986), Harvey et al (1975), Mummery (1978), Fyfe and Chahl (1984), Mortimer and Dyson (1988), Young et al (1990a, 1990b, 1990c) and others provide information that suggests the occurrence of a number of physiological changes in soft tissue structures due to the use of low intensity ultrasound.

The primary non-thermal effects of ultrasound are (1) acoustic cavitation, (2) microstreaming and (3) the production of radiation forces.

Ter Haar (1987) and Hill and ter Haar (1989) describe acoustic cavitation as the production and oscillation of small bubbles of gas or vapour within a liquid. Hill and ter Haar (1989) state that, through this mechanism, sound energy may be converted into other forms of energy such as shear energy (microstreaming), heat energy (due to collapse of the bubbles) and chemical energy (due to the release of free radicals).

Bubbles are produced as a result of a reduction in hydrostatic pressure during the rarefaction phase of the acoustic cycle and appear at a critical point in the cycle, known as the threshold level (Frizzell and Dunn, 1990). The threshold level is dependent on a number of factors which are specific to the local environment and include temperature, pressure, acoustic frequency, the kind and amount of dissolved gas and the previous history of the medium.

Both stable and unstable, or transient, cavitation may occur. Stable cavitation occurs when the bubbles continue to expand and contract in a steady state. In a medium experiencing a tension stress during a portion of the rarefaction phase, the bubbles make large excursions which culminate in their collapse during the compression phase, resulting in unstable cavitation. This collapse may be due to surface instability and is associated with great increases in local temperature and pressure (Hill and ter Haar, 1989). ter Haar and Daniels (1981) present evidence to suggest that stable cavitation occurs in soft tissue, though both Hill (1972) and Hill and ter Haar (1989) suggest that cavitation is less likely to occur with pulsed radiation. Frizzell and Dunn (1990) note that chemical reactions have been associated with the cavitation phenomenon; ionisation is suggested to occur in the atmosphere of the bubble. This may promote chemical reactions, such as the production of ions and free radicals which might affect cell behaviour.

<u>Acoustic microstreaming</u> is flow within a viscous medium (Nyborg, 1965). It is due to the acoustic radiation force and the momentum set up at specific points within a medium. It is enhanced as a result of stable cavitation and leads to localised liquid flow around the bubbles and, consequently, adjacent to cells. Repacholi (1970), Repacholi et al (1971) suggest that microstreaming may alter ionic permeability and secondary messenger activity, and be responsible for changes in the surface charge of cells, resulting in the transduction of signals. Greater intensities, however, may lead to cell damage and rupture due to the high shear forces generated (Williams, 1972).

Both Dyson (1985) and Young (1988) have suggested that microstreaming at therapeutic doses may influence cell function by affecting the integrity of the cell membrane and modifying the local environment through mechanisms such as altered cell metabolite gradients.

Radiation forces result when the momentum transported by the acoustic wave process changes with position in the medium and most frequently occurs at an interface between two materials of differing acoustic characteristics (Dunn and Frizzell, 1990). These forces can lead to the production of standing waves. Standing waves consist of two superimposed waves, an incident and reflected wave, which exhibit high peak intensities and pressures (Dyson, 1990). Net radiation forces affect bodies which lie within the sound field and result in free cells moving to the point of pressure minima and gas bubbles move to pressure maxima. This effect may explain the cell banding reported by Dyson et al (1974) in the vascular system of a chick embryo when ultrasound was delivered at 3 MHz as a standing wave; Dyson (1990) however, suggests that the phenomenon is unlikely to occur in clinical practice which tends to utilise low doses of sound energy.

Shortwave diathermy

Whereas continuous shortwave diathermy is believed to achieve its effects through thermal changes, the pulsed agent is thought by many to achieve its effects in other ways. Little work has been done, however, to examine the physiological effects of pulsed shortwave diathermy on cells and tissues, with the consequence that very little is known about the effects of this form electromagnetic energy on healing (Barker and Freestone, 1985).

The mechanisms may be similar to those hypothesised and identified for other frequencies of electromagnetic energy, but care must be taken in extrapolating from one to another as there is evidence to suggest that effects may be frequency specific (Schwan, 1985; Westerhoff, 1986; Frohlich, 1988; Tsong, 1989).

Much work has been undertaken in the last ten years on the effects of electromagnetic fields on cellular activity (Frohlich, 1988; Adey, 1988; Stulchy, 1990) but has primarily focused on the examination of very low frequency currents and microwave (Adey, 1988). The mechanisms postulated for the action of these frequencies on tissue are presented here as they may relate the mechanisms whereby pulsed shortwave diathermy reacts with tissues. These are (1) transduction theory (Adey, 1988), (2) cyclotron resonance mechanism (Liboff, 1985) and (3) electrochemical stimulation (Pilla, 1972).

1. Transduction theory: Adey (1988) postulated the transduction of a pulsed magnetic field (PMF) signal across the cell membrane, regarding the cell membrane as the primary site of interaction between the oscillating electrical field and the tissue. He suggested that major amplification of an initial weak trigger occurs as the result of the binding of hormones, antibodies and neurotransmitters to their specific binding sites on the cell membrane and discounts both temperature changes and ionisation as possible mechanisms.

The theory proposed by Adey (1988) is made up of three stages; firstly he suggests that the electrical signal results in the binding of the former substances to receptor sites. This leads to a modification of calcium binding to the glycoproteins along the surface membrane. Secondly, signals from the receptor sites are transmitted into the cell to the cytoplasm via the intramembranous particles supporting the glycoprotein receptor sites. Finally, intracellular responses occur as a result of the transmembrane signal.

Adey (1988) notes that amplification appears to occur as a result of the calcium binding, greater fluxes occurring than are accounted for by the energy imposed. He also notes that experimental work suggests a nonlinear response to stimuli of differing frequencies and amplitudes, 'windows' of maximum response existing (Bawin et al, 1978; Adey, 1981; Lin-Liu and Adey, 1982).

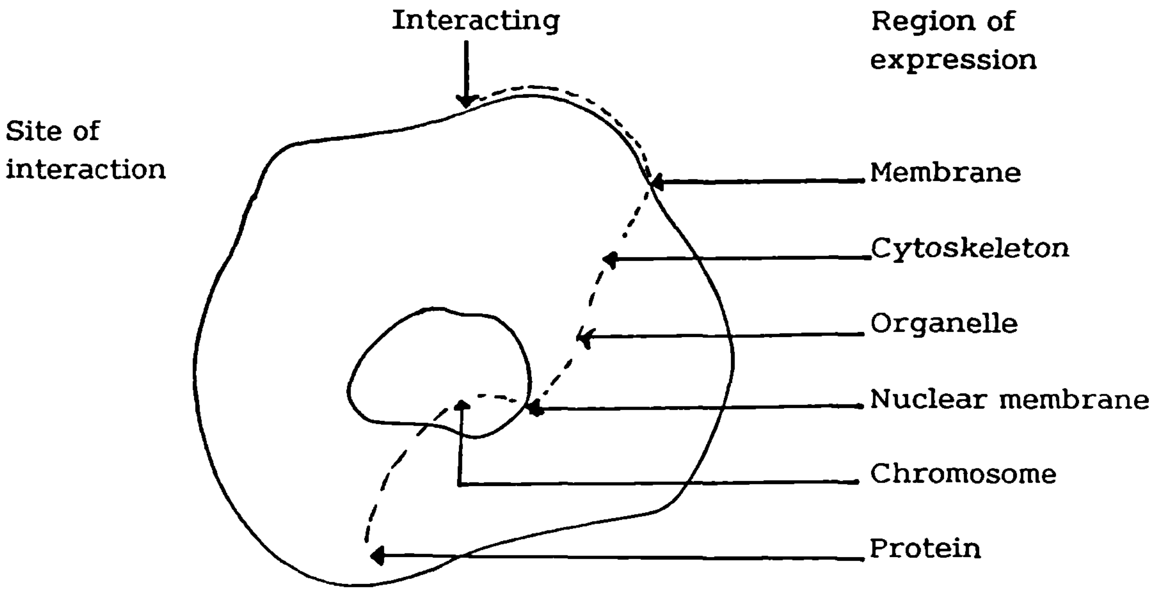
Tsong (1989), Westerhoff (1986) and Astumian et al (1987) describe an alternative model of cell transduction termed electroconformational coupling (ECC). This model postulates that proteins can undergo conformational changes due to interaction with an oscillating electrical field. The frequency of the field must match the kinetic characteristics of the reaction and be at an optimum field strength (Tsong, 1989). This can lead to pumping effects across the membrane and adenosine triphosphate (ATP) synthesis. Each class of protein responds to a defined frequency and strength of oscillating electrical field.

Computer modelling of wave forms has identified certain patterns which are shown to work with the ECC model. On the basis of previous work examining the behaviour of Na^+, K^+ and ATP, Westerhoff et al (1986) examined the possibility of enzymes capturing free energy from an oscillating electrical field through the use of models and calculations. They demonstrated that the net consequence of one complete cycle of the oscillating field would be a cyclic turnover of enzymes. Evidence suggests that the phenomenon is not closely dependent on the wave form of the field. Westerhoff et al (1986) suggest that both fields with a time average value of zero (cyclic fields) and those with a positive time average value (pulsed fields) will harvest free energy, thought they suggest that the former is a more efficient system. Astumian et al (1987) demonstrated, again through the use of a similar model to Westerhoff et al (1986) that enzymes can also transduce energy from a randomly pulsed electrical field. Random electric noise may also under certain circumstances induce cyclic flux in the model enzyme. This model does not indicate that a constant electrical field will allow an enzyme to transduce energy.

Expanding on the work of Muller (1983), who suggested that an oscillation in temperature might allow a biological system to absorb free energy, Westerhoff et al (1986) note that an electrical field is a 'thermodynamic quantity' and suggest that it may be the oscillation in this parameter which results in the enzyme cycle.

2. Cyclotron resonance mechanism: Liboff, in 1985, suggested that ion cyclotron resonance explained the coupling of pulsed magnetic field energy to cells and that the ion flow through cellular plasma could be predicted by this mechanism. Cyclotron resonance has been described for free particles; when a particle enters a static magnetic field, it experiences a force at right angles to both the particle velocity and the field. This can result is either a circular or helical motion of the particle (Liboff, 1985). Liboff proposes that this mechanism may be restricted to the cell membrane and pre-existing pathways through that structure. Oscillating or electrical magnetic fields may 'act to transfer kinetic energy to channel ions' and the Na^{+}/Ca^{2+} and K^{+}/Ca^{2+} transmembrane exchange mechanisms be enhanced (Liboff, 1985). Liboff (1985) postulates that the membrane effect then results in a cascade response within the cell leading to changes in cell behaviour, as demonstrated in figure 4.

Figure 4. Cascade of cell responses (adapted from Liboff, 1985)



In this example the interaction occurs at the membrane and leads to a cascade of six responses in the structures noted.

Blackman et al (1984) demonstrated a large Ca^{2+} efflux across cell membrane at 30 Hz whilst Smith et al (1987) and Liboff et al (1987) studied the effects of cyclotron resonance on calcium uptake by diatoms and lymphocytes respectively. Liboff et al (1987) showed that uptake was dependent on the frequency and amplitude of the oscillatory fields used and suggested that interactions between cells and electromagnetic fields may only occur at certain energy 'windows'. Similar behaviour was reported by Smith et al (1987) in their studies with diatoms.

Finally, Liboff (1985) highlighted the importance of the frequency of the electromagnetic in achieving cellular responses as ions are frequency specific and he and his colleagues demonstrated, in 1987, that Ca^{2+} ions were maximally taken up by human lymphocytes at a frequency of 14.3 Hz.

3. Electrochemical stimulation: Relatively little information is available about this theory; in 1974 Pilla suggested that electrochemical interactions might occur at the cell membrane, resulting in altered cellular activity and development. He notes that the cell membrane exhibits capacitor-like properties as it separates the electrical charges on the two sides of the structure and stresses its 'leaky' nature, transmembrane ion transport occurring. Pilla (1985) suggests that currents can cross the cell membrane through a set of electrochemical steps. Such activity occurs at sites of

natural trauma and Pilla (1974) proposes that pulsed electromagnetic energy may stimulate similar changes. In support of his theory, Pilla (1974) and (1980) reported using a low frequency pulse-burst wave form (15 Hz) in the treatment of un-united fractures in children; healing following the use of these waves resulted in response rates lying between 70-80%.

As has been stated previously, none of these theories have been examined in relationship to pulsed shortwave diathermy; particular caution is required as in almost all cases investigators emphasise the importance of frequency and sometimes intensity on the cellular reactions. Considerable work is required in this area before any conclusions can be drawn.

Laser

Ohshiro and Calderhead (1988) state that the photobioactivation resulting from the application of laser occurs at two levels; the tissues respond firstly at a local, cellular level and, secondly, at a systemic level.

Local effects have been examined and discussed by Karu (Karu et al, 1984; Tiphlova and Karu, 1987; Karu, 1988; Karu, 1991) and a model for low level laser radiation (red light) stimulation of biological systems postulated (Karu, 1987). Initially, energy imparted by the laser is absorbed by chromophores, or light absorbing biological molecules. Karu (1988) proposed that, following such absorption, a chain of molecular events might occur leading to the photochemical effects of laser; she proposed that light, absorbed by a photoreceptor, led to signal transduction and amplification.

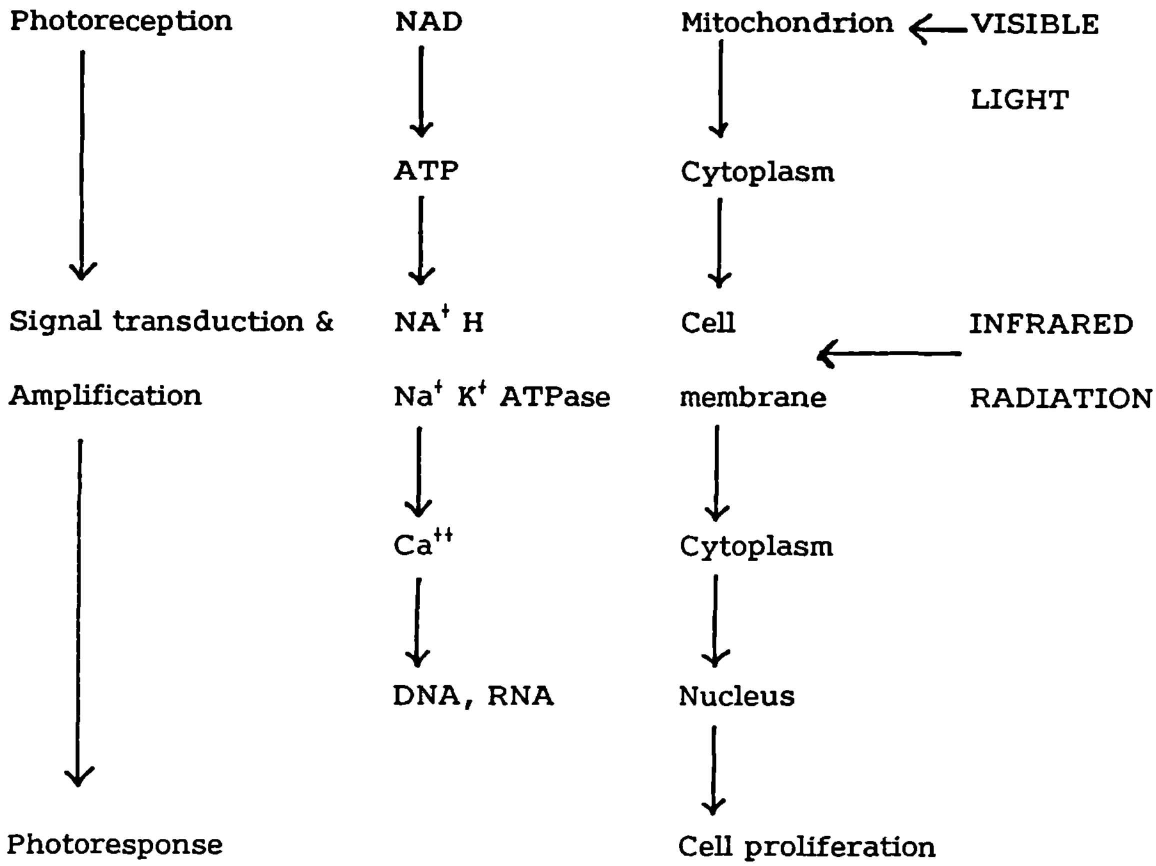
Karu (1988) postulated the following sequence of events; light, absorbed by components of the respiratory chain within the mitochondria, causes a brief activation of that chain. Oxidation of the NAD pool occurs leading to changes in the redox status of the mitochondria and cytoplasm. Membrane permeability, and consequently transport, is altered with changes in the Na^+/H^+ ratio occurring and increases in Na^+/K^+-ATPase activity. The Ca^{++} flux is consequently altered, resulting in modulation of DNA and RNA synthesis and consequent changes in cell growth and proliferation.

Karu (1988) reviewed work conducted by her team on the observed effects of light on molecular mechanisms in E coli, yeast and mammalian cells; increased synthesis of ATP and DNA, and a reduction in the intracellular pH were reported (Karu 1988). Further work, reported in 1992, confirmed that the level of ATP in He-La cells increased after irradiation with laser light, gradually returning to normal after a period of 45 minutes.

Smith (1991a,b) suggested certain modifications to this model; he proposed that different frequencies of laser may activate this chain at different points. Radiation at 633 nm may initiate activity at the mitochondrial level, as suggested by Karu (1987), whereas at 904 nm it may initiate reactions at the cell membrane level, possibly through photophysical effects on Ca^{++}

channels (Smith, 1991a). Both would ultimately result in a final common pathway of events as seen in figure 5.

Figure 5. <u>A model for low level laser radiation activation of biological tissues (Smith, 1991a)</u>



This model has received support from the work of Yamaya et al (1993), who showed that receptors exist on the membrane of the human neutrophil which, when stimulated with 830 nm laser, resulted in an increase in the phagocytic activity of the cells.

The more generalised, systemic effect mentioned by Ohshiro and Calderhead (1988) may be actuated through enzyme activity. Light activation of enzymes has been reviewed by Hug and Hunter (1981; 1991). Enzymes are catalysts and it has been suggested that one photon of light energy can activate one enzyme molecule, which will in turn activate many substrate molecules, resulting in a cascade effect (Smith, 1991a). A huge amplification factor therefore exists for stimulating biological processes through the action of low levels of light energy.

Drawing on information from studies of ultraviolet irradiation as well as laser, it is suggested that laser may activate the enzyme directly or indirectly induce its synthesis (Smith, 1991b). Direct activation of enzymes may be accomplished by stimulating a photoconformational change in the enzyme molecule, stimulating an attached photochromatic inhibitor of the enzyme or through splitting an inhibitor from the enzyme through photochemical means. Indirect activation may occur through enzyme synthesis due to gene activation and the activation of substrate and enzyme-substrate complexes; thus ultraviolet irradiation as been shown to result in the synthesis of tissue repair enzymes and laser (633 nm) to stimulate the synthesis of procollagen (Hug and Hunter, 1991; Saperia, 1986). The last two mechanisms do not demonstrate amplification and are therefore less likely candidates for laser interaction than direct stimulation and genetic activation (Smith, 1991a: Hug and Hunter, 1991).

Tissue healing may be facilitated through one or more of these mechanisms; in the following chapter the processes of repair are considered.

Section I. Chapter 4.

SOFT TISSUE HEALING

Physiotherapists treat both acute and chronic inflammatory lesions, open and closed wounds and problems associated with the healing process such as oedema and haematomas. Use has been made in the past of ultrasound, continuous and pulsed shortwave diathermy and laser to manage such lesions and initiate or enhance the repair process. In order to be able to understand how electrophysical agents may affect the healing of soft tissue lesions, and the reasoning which lies behind their selection and application, it is essential that the processes underlying healing be examined in some detail.

Healing is a complex, but essential, process without which the body would be unlikely to survive. It involves the integrated actions of cells, matrix and chemical messengers and aims to restore the integrity of the tissue as rapidly as possible. Lapière (1991) describes healing as a homeostatic mechanism, designed to restore physiological equilibrium.

Healing follows injury to the soft tissues of the body. Injury may be the result of surgical intervention, accidental injury or result due to the indolent state of tissue. Injury affects skin, ligaments, tendons and muscle and may be either open or closed in nature and is normally accompanied by damage to the local vascular and nervous systems. Healing may be initiated as a result of loss of communication between adjacent cells, between cells and their support, or by cell death (Lapière, 1991).

Lapière (1991) notes the similarities between healing and the normal development, growth and aging of the body and describes the process in terms of chemokinesis, cell multiplication and differentiation. A complex series of events occurs, involving the migration of cells of vascular and connective tissue origin to the site of injury. This process is governed by chemotactic substances liberated in situ. The healing process, which is common to all body tissue types, may be divided into three, overlapping phases; these are the phases of (1) inflammation, (2) proliferation and (3) remodelling. Healing of all tissue is based upon the basic three phases described below and frequently results in the formation of scar tissue. Limited regeneration of certain tissues such as the epidermis, skeletal muscle and adipose may, however, occur.

The basic principles under lying healing and leading to scar formation will first be described. Subsequently, a brief summary of the regenerative healing of epidermal and muscular tissue is provided.

THE PRINCIPLES OF TISSUE HEALING

Inflammatory Phase

Inflammation is the immediate response to injury. The cardinal signs of inflammation are redness, swelling, heat and pain. The acute, or early phase, inflammatory response, lasting for between 24 and 48 hours is followed by a subacute, or late, phase which lasts for between ten and 14 days (Clark, 1988).

The subacute phase can be extended if there is a continuing source of trauma or if some form of irritation, such as a foreign body or infection, is present. This phase can last for months or even years under these circumstances and is termed chronic inflammation.

Tissue injury causes both cell death and blood and lymph vessel disruption. The primary purpose of the inflammatory phase of healing is to rid the area of debris and dead tissue and destroy any invading infection prior to the repair. This phase may be described in terms of vascular and cellular changes which are mediated through the actions of chemical agents.

Vasoregulation and blood clotting: The initial vascular reaction involves haemorrhage and fluid loss due to destruction of vessels; vasoconstriction and vessel plugging, to prevent further blood loss, and blood coagulation follow. These processes lead to the activation of the repair process. Blood extravasion initiates platelet activity (Terkeltaub and Ginsberg, 1988) and blood coagulation directly (Furie and Furie, 1988), both of which then result in the production of chemical factors which initiate and control the healing process. In addition, the blood clot provides a provisional matrix which facilitates the migration of cells into the wound (Clark, 1991).

Primary vessel constriction is due to the release of norepinephrine and this reaction lasts for a few seconds to minutes only. During vasoconstriction of the vasculature, the opposing cell walls are brought in contact resulting in adhesions occurring between the surfaces. Secondary vasoconstriction may follow, due to the action of serotonin, adenosine diphosphate, calcium and thrombin (Clark, 1991).

Both lymphatics and blood vessels are plugged in order to limit fluid loss. Initial platelet adhesion and aggregation is stimulated by the presence of thrombin, released by the platelets themselves, and exposed fibrillar collagen (Terkeltaub and Ginsberg, 1988). The platelets adhere to one another, the vessel walls and the interstitial extracellular matrix. They continue to release adenosine diphosphate (ADP) and further thrombin, leading to the build up of relatively unstable platelet plugs (Clark, 1991). The process is continued and consolidated by the release of adhesive proteins such as fibrinogen, fibronectin, thrombospondin and von Willebrand factor by the platelets (Ginsberg et al, 1988).

Coagulation of extravascular blood is thought to be due to the action of platelets, and the role of the intrinsic and extrinsic clotting mechanisms (Clark, 1990a). Hageman factor (factor XII), activated by adsorption onto exposed fibrillar collagen, activates the intrinsic clotting mechanisms. The extrinsic clotting mechanism is activated through the activation of factor VII as a direct result of tissue damage. Platelets, activated by thrombin and contact with fibrillar collagen, release coagulation factors which form an integral part of the clotting mechanism and thus assist the process. The summative effects of these processes is that prothrombin is converted to thrombin and thus fibrinogen to fibrin, providing an early wound matrix (Clark, 1990a; 1991).

Blood coagulation aids haemostasis through clot formation, provides an early wound matrix and results in the generation of chemical mediators (Clark, 1991); these include bradykinin (Proud and Kaplan, 1988) and, indirectly, anaphylatoxins C5a and C3a (Ghebrehiwet et al, 1981). These substances affect the local circulation, stimulate the production of further chemical mediators and act as attractants to cells such as neutrophils and monocytes (Clark, 1990a).

Following this period of vasoconstriction, secondary vasodilation and increased permeability of venules occurs and is initially due to the effects of histamine, prostaglandins and hydrogen peroxide production (Issekutz, 1981; Williams, 1988). Subsequently, both bradykinin and the anaphylatoxins initiate mechanisms which increase the permeability of undamaged vessels, leading to the release of plasma proteins which contribute to the generation of the extravascular clot.

Cell migration and action: Neutrophils and monocytes are the earliest cells to reach the site of injury, and migrate in response to a wide variety of chemical and mechanical stimulants including the products of the clotting mechanism, the presence of bacteria and cell derived factors (Clark, 1991).

Neutrophilic margination within the vascular structures leads to their passage through vessel walls by amoeboid action in order that the cells may reach damaged extravascular tissues. Their primary action is phagocytosis and their task is to rid the site of bacteria and dead and dying materials (Clark, 1991). Neutrophilic lysis follows and results in the release of protease and collagenase which begin the lysis of necrotic protein and collagen respectively (Peacock, 1984). Infiltration ends after a couple of days, marking the end of the early phase in inflammation (Clark, 1988).

Monocytes migrate from the vasculature into the tissue space and rapidly differentiate into macrophages (Riches, 1988); the factors responsible for this change are unclear but may include the presence of insoluble fibronectin (Hosein et al, 1985), low oxygen tension (Hunt, 1987), chemotactic agents (Ho et al, 1987) and the presence of bacterial lipopolysacarides and interferons (Riches, 1988). Macrophages are essential to the healing process and can perform the normal function of neutrophils in addition to their other tasks. They phagocytose pathogenic organisms, tissue debris and dying cells, including neutrophils, and release collagenase and proteoglycan, both of which are degrading enzymes which lyse necrotic material (Leibovich and Ross, 1975; Tsukamoto et al, 1981).

Chemical factors: Many factors are released by cells during the stage of inflammation which influence and control the initial inflammatory process and trigger further developments in the proliferative phase. Macrophages release factors which attract fibroblasts to the area (Tsukamoto et al, 1981) and enhance collagen deposition (Weeks, 1972; Clark, 1985). They synthesise and secrete factors such as platelet-derived growth factor (PDGF) (Shimokado et al, 1985, Martinet et al, 1986), basic fibroblast growth factor (bFGF) (Baird et al, 1985), transforming growth factor-α (TGF-α) (Madtes et al, 1988), transforming growth factor-ß (TGF-ß) (Assoian et al, 1987), insulin-like growth factor-1 (IGF-1) (Rom et al, 1989), tumour necrosis factor-α (TNF-α) (Kreigler et al, 1988), interleukin-1 (IL-1) (Prostlethwaite et al, 1983) and fibroblast activating factor (FAF) (Dohlman et al, 1984), all of which are necessary for new tissue formation (Madtes et al, 1988).

Platelets release growth factors, such as TGF-α, (Derynck, 1988), TGF-ß (Sporn et al, 1987; Wahl et al, 1987), PDGF (Deuel and Huang, 1984; Ross et al, 1986), platelet activating factor (PAF) (Hanahan, 1986) and platelet factor-4 (PF4) (Deuel et al, 1981). These contribute to the control of fibrin deposition, fibroplasia and angiogenesis through their action on a variety of cells (Clark, 1991). Platelets also release fibronectin, fibrinogen, thrombospondin and von Willebrand factor (Ginsberg et al, 1988); these are necessary for platelet aggregation and binding to tissue structure. In addition serotonin, adenosine diphosphate, calcium and thromboxin are released and are necessary for blood vessel constriction for the prevention of haemorrhage (Clark, 1991).

Dead and dying cells release substances which influence the development of the neomatrix; these including a variety of tissue factors, lactic acid, lactate dehydrogenase, calcium, lysosomal enzymes and fibroblast growth factor (Clark, 1990a).

Prostaglandins (PG) are produced by almost all cells of the body following damage due to alterations in the phospholipid content of the cell walls (Janssen et al, 1991); some types of PG are proinflammatory, increasing vascular permeability, sensitising pain receptors and attracting leucocytes to the area. Other classes of PG may be anti-inflammatory. Both may be involved in early stages of repair.

Proliferative Phase

During the proliferative phase granulation tissue is formed; this is a temporary structure which evolves after a period of a couple of days and comprises neomatrix, neovasculature, macrophages and fibroblasts. Granulation tissue precedes the development of mature scar tissue (Clark, 1991). 'Fibroplasia' encompasses the processes of fibroblast proliferation and migration, and the development of the collagenous and non-collagenous matrices (Clark, 1990b).

Fibroplasia: Fibroblasts produce and organise the major extracellular components of the granulation tissue. Present evidence suggests that fibroblasts are most likely to originate from resting fibrocytes situated in the wound margins (Skalli and Gabbiani, 1988); they migrate into the wound under the influence of three factors. These are (1) chemical attractants such as TGF-ß and PDGF, (2) the assistance of non-collagenous protein (especially fibronectin) which presents adhesion gradients and (3) through 'contact guidance' associated with the physical arrangement of the extracellular matrix fibres (Repesh et al, 1982; McCarthy et al, 1988; Clark, 1990b).

Fibroblasts proliferate within the granulation tissue under the influence of a wide range of factors, including FGF and PDGF, the majority of which are produced by macrophages (Wahl, 1985; Paulsson et al, 1987). Due to the activity of growth factors and chemical attractants fibroblasts may undergo change and become termed myofibroblasts, possibly becoming involved in wound contraction processes.

The fibroblast is primarily responsible for the deposition of the new matrix. Once present within the wound, fibroblasts synthesise hyaluronic acid, fibronectin and types I and III collagen; these form the early extracellular matrix (Clark, 1990b). As the matrix matures, certain changes take place. Hyaluronic acid and fibrinogen gradually disappear, type I collagen becomes the predominant component and proteoglycans are deposited.

Hyaluronic acid, present only early in wound healing appears to facilitate cell motility and may be important in fibroblast proliferation (Toole, 1981; Lark et al, 1985). Fibronectin has many functions within a wound; these include acting as a chemoattractant to cells such as fibroblasts and endothelial cells, augmenting the attachment of fibroblasts to fibrin, facilitating the migration of fibroblasts and possibly providing a template for collagen deposition (Clark, 1988). Proteogycans contribute to tissue resilience and help to regulate cell motility and growth and the deposition of collagen.

Collagen is a generic term covering a number of different types of glycoprotein found in the extracellular matrix (McPherson and Piez, 1988). Collagen provides a rigid network which facilitates further healing. The types of collagen within a wound and its deposition are gradually modified with time. Type III (embryonic collagen) is gradually absorbed and replaced by type I collagen, which is mature fibrilar collagen. Type IV collagen may be produced as a part of the basement membrane when skin damage to this level has occurred and type V collagen is deposited around cells, forming a structural support.

Kulozik et al (1991) highlights the two factors which affect collagen metabolism and therefore production. The first is the effect of the cytokines. Most information about these has been gathered from *in vitro* studies, with little follow up work in the area of *in vivo* studies. There appears, however, to be a constant balance between the stimulatory and inhibitory effects of the many substances at each stage of the healing process, designed to induce optimal healing with neither over nor under production of collagen. Table 1 lists some of the cytokines believed to affect the process.

Table 1. Cytokines controlling collagen production

TGF-ß	induces collagen synthesis	(Ignotz and Massague, 1986)
IL-1	induces collagen synthesis	(Postlethwaite et al, 1988)
TNF	induces collagen synthesis	(Duncan and Berman, 1989)
IFN(α,ß,γ)	decreases collagen synthesis	(Czaja et al, 1987)
TNF-α	decreases collagen synthesis	(Scharffetter et al, 1989)
PGE_2	decreases collagen synthesis	(Nicholas et al, 1991)

Key: TGF-ß, transforming growth factor ß; IL-1, interleukin 1; TNF, tumour necrosis factor; IFN, interferons; PGE_2, prostaglandin E_2

The second factor influencing collagen metabolism is the nature of the extracellular matrix (Kulozik et al, 1991). The extracellular matrix provides both a structural scaffold for the tissue and signalling for the cells. Mauch et al (1988) showed that the growth of fibroblasts is reduced when they are embedded in a three dimensional collagen matrix; reduced collagen synthesis results from cell contact with mature, type I collagen and the production of collagenase is activated.

Production of collagen may also be inhibited through a feedback mechanism (Mauch et al, 1988); procollagen is initially produced with two large procollagen peptides located at each end of the structure; these are cleaved off and enter the matrix pool. They then proceed to act as feedback inhibitors. Mauch et al (1988) noted that the presence of mature collagen increased the cleavage rate and Mauch and Krieg (1990) demonstrated that there was an associated decrease in the collagen production rate. Thus over production of scar tissue should normally be avoided.

Angiogenesis: An extensive vascular system is required to provide for the needs of this phase. Angiogenesis has been described by Ausprunk and Folkman (1977) and Ausprunk et al (1981) and has been reviewed in detail by Zetter (1988) and Madri and Pratt (1988). It is a complex process involving endothelial phenotype alteration, migration, proliferation and the generation of an appropriate extracellular matrix (Madri and Pratt, 1988).

Angiogenesis is thought to be initiated by the presence of multiple angiogenic stimuli (Zetter, 1988). The process of capillary budding initially involves the disruption of the basement membrane of the venule at a point adjacent to the angiogenic stimulus, possibly as a result of the action of the endothelial cells themselves (Gross et al, 1983); endothelial cells then migrate towards the stimulus as a cord of cells surrounded by a provisional matrix (Ausprunk et al, 1981; Clark et al, 1982b). Individual sprouts link to form capillary loops, which may in turn develop further sprouts. Lumina appear within the arched cords and blood flow is gradually established, initially in immature, permeable vessels and later in more mature capillary beds having developed basement membrane components (Ausprunk et al, 1981; Hashimoto and Prewitt, 1987).

The anastomosis of existing vessels and the coupling or re-coupling of vessels within the wound space also occurs, leading to a well developed and copious blood supply within the granulation tissue (Clark, 1990a). This state is not, however, retained as the granulation tissue is later remodelled into scar tissue. Capillary regression occurs, possibly in response to a loss of angiogenic stimuli, and is characterised by changes in the mitochondria of the endothelial cells, their gradual degeneration and necrosis and final ingestion by macrophages (Ausprunk et al, 1978; Folkman, 1982).

Angiogenesis is stimulated and controlled through the action of many substances; these have been reviewed by Folkman and Klagsburn (1987), Madri and Pratt (1988) and Zetter (1988). Effects may be both direct and indirect and arise from stimuli generated both at the time of injury and during the early stages of repair (Clark, 1990a). They include growth factors such as FGF and prostaglandins which are produced by macrophages, platelet derived factors such as platelet derived endothelial cell growth factor and TGF-ß, thrombospondin, heparin and the presence of fragments of fibronectin (Folkman and Klagsburn, 1987; Zetter, 1988). Low oxygen tension may stimulate activity either directly or indirectly (Knighton et al, 1983). Heparin, released by mast cells, and fibronectin fibrils act as attractants to draw the endothelial cells through the vessel walls to form the capillary buds (Clark, 1991).

Wound contraction: Contraction is the process that reduces the size of a wound and is due to the centripetal movement of pre-existing tissue (Montadon et al, 1977; Peacock, 1984). Wound contraction in loose skinned animals, such as rabbits and rats, is a major form of wound closure; it rarely leads to loss of function. Rudolph et al (1991), however, noted that, in humans, wound contraction is a 'double edged sword': too little and wound closure is slow, allowing excess bleeding and possible infection; too much and tissue contractures may occur leading to deformity and disfunction. Alone, wound contraction rarely closes a human wound.

Beginning soon after injury, wound contraction peaks at two weeks. Many theories have been posited as to the mechanism of wound contraction, though few have survived long (van Winkle, 1967). Most recent work suggests that material within the defect may pull the margins of the wound inwards. Two theories currently are currently postulated for this process; they are the cell contraction theory, based on the actions of myofibroblasts (Gabbiani et al, 1971), and the cell traction theory, based on the action of fibroblasts (Ehrlich and Rajaratnam, 1990).

The cell contraction theory suggests that the contractile activity of myofibroblasts draws the edges of the wound together against the constant centrifugal tension of the surrounding tissues (Gabbiani et al, 1971; 1973; Rudolph et al, 1991). Both actin and myosin have been identified in myofibroblasts (Gabbiani et al, 1973; Vande Berg et al, 1989) and it is suggested that these cells attach themselves to collagen fibres and then retract, holding the collagen in place until it has stabilised its position (Rudolph, 1980). The theory suggests that the synchronised activity of the many myofibroblasts will lead to wound shrinkage (Skalli and Gabbiani, 1988).

The cell traction theory suggests that fibroblasts are the agents of closure by exerting 'traction forces' on the extracellular matrix fibres to which they are attached; the process is analogous to the traction exerted by wheels on a surface. Traction forces are shear, tangential forces which are generated during cell activity. Harris et al (1981) noted that when fibroblasts are grown on distortable silicone sheets, they elongate and spread leading to a 'gathering up' of the material. Ehrlich and Rajaratnam (1990) have suggested this as the mechanism most likely to produce wound closure.

Much argument surrounds the viability of these two theories; current evidence suggests that the event is cell mediated and that the cells involved are of fibroblastic origin (Hart, 1993). Some studies suggest that wound contraction appears to start before many myofibroblasts are present in the area, implicating fibroblastic activity (Rudolph, 1979; Ehrlich and Hembry, 1984; Darby et al, 1990); this does not however preclude the suggestion that both mechanism may be involved in the process in a sequential fashion (Hart, 1993).

Remodelling

Remodelling of the immature tissue matrix commences at about the same time as new tissue formation, though for clarity it is normally regarded as forming the third phase of healing. The matrix which is developed at this stage is gradually replaced and remodelled over the subsequent months and years as the scar tissue matures (Clark, 1990b).

In the early stages of wound healing, collagen is immature and gel-like in construction and exhibits little tensile strength. Remodelling occurs over a period ranging f om several months to years, developing type III collagen being partly replace by type I. Fibres re-orientate themselves along the lines of stress applied to the lesion, thus resulting in greater tensile strength of the tissue (Price, 1990). Wound breaking strength increases with the deposition of collagen, reaching approximately 20% of the normal by day 21. The final strength attained will be in the region of 70-80% of the normal value (Daly, 1990; Price, 1990).

REPAIR OF SPECIALISED TISSUES

The repair of certain specialised tissues may result in a number of modifications or additions to the normal healing process. A brief description is given of the processes which may occur when epidermal and muscle tissue are damaged.

Epidermal tissue

Injuries to the skin may involve either the epidermis alone, as may be the case in very superficial lesions or blisters, or both the epidermis and the dermis. When the skin is broken, a major defence of the body to invasion by pathogens is breached and the subject is exposed to infection by a wide variety of organisms which can lead to further tissue damage and disease. Rapid coverage of the surface is essential, reducing the hazards associated with environmental stress and contamination. While dermal healing continues as described above, re-epithelialisation of the surface occurs to close the wound surface.

The process of re-epithelialization involves the restoration of epidermal continuity and the subsequent normalisation of the epidermal architecture.

Re-epithelialisation is initiated within 24 hours of injury. Epidermal basal cells undergo changes which allow them to migrate toward the site of the lesion; they loosen their intercellular attachments (desmosomes), retract their intracellular tonofilaments resulting in a loss of cellular rigidity and develop actinic pseudopodia, all of which facilitate mobility on the part of the cell (Gabbiani et al, 1978; Clark, 1985; Clark, 1990a).

Epidermal cells migrate rapidly towards the base of a wound, travelling across the remaining viable basal lamina or the fibrin scaffolding of the blood clot formed in deeper lesions (Hunt and Dunphy, 1980; Clark, 1990a). Cells move across the wound surface in response to a number of substances in the wound matrix, including fibronectin, fibrin and collagen (type IV) which provide a structural network for migration (Hunt and Dunphy, 1980). The pattern of migration is as yet unclear; a train of cells may progress across the surface (Clark, 1985) or, alternatively, a 'leapfrog' mechanism may occur in which cells slide over one another as they move forward (Krawczyk, 1971; Winter, 1972).

Clark (1985; 1991) notes that there is a certain lack of clarity about the factors which initiate and promote the restructuring process; however, they include chemotactic factors, structural macromolecules, degradative enzymes, tissue geometry such as the free edge effect, fibrin, collagen, fibronectin, thrombospondin and growth factors. The stimulus for epithelialization and the exact process is still debated, though epidermal growth factor or TGF-α are likely signals for cell proliferation (Barradon and Green, 1987). The factors responsible for the initiation, inhibition and cessation of migration have been considered by Estensen et al (1973), Clark (1985) and Hunt and Dunphy (1980); Estensen and colleagues (1973) first suggested that cyclic guanosine monophosphate might act as a 'go' signal and cyclic adenosine monophosphate as a 'stop' signal to cell motility.

Epidermal differentiation follows migration; mitotic activity, controlled by the cyclic AMP system, increases in the newly formed epithelium resulting in thickening of the tissue and the development of a normal stratified appearance (Matolsty and Viziam, 1970; Odland and Ross, 1977; Green, 1978). Normal keratinisation follows, initially in the upper most layers, followed by the development of a full stratum corneum (Potten and Allen, 1975; Odland and Ross, 1977).

Finally, the epidermis returns to normal. When the basement membrane is present and the re-epithelialisation complete, the cells resume their normal appearance and the hemidesmosomes reform to link the basement membrane and the epidermal layer of cells (Clark, 1990a). Where deficient, the basal lamina is synthesised by the epidermal cells over a infrastructure of newly formed collagen (Clark et al, 1982a).

Muscle Tissue

Despite a widespread belief that muscle tissue is incapable of regeneration, Studitsky (1964) pioneered studies which showed that muscle cells can regenerate following injury; the degree to which regeneration takes place appears to depend on the degree to which the basement membranes of the original fibres have been retained, and the vascular and nerve supply to the area (Carlson and Faulkner, 1983).

Carlson (1973) describes muscle repair in terms of the removal of damaged cell components, satellite cell proliferation to form new muscle fibre building materials and satellite cell fusion to form new myotubes and muscle fibres.

The process involved in the early degenerative phase has been reviewed by Carpenter and Karpati (1984); myofibrils loose their regularity and disorganisation of the Z-disc appears to occur. Mitochondria become more rounded and loose their regular distribution within the cell. Actin and myosin filaments loose their regularity, glycogen particles disappear and tissue no longer stains positive for the enzymes such as phosphorylase, used in glycogenolysis.

Proliferation of skeletal muscle satellite cells (or presumptive myoblasts) follows; these provide a source of myonuclei for the regenerating muscle cells. Bischoff (1986; 1990) hoped to identify the factors which might initiated this process; he suggested that under normal conditions the sarcolemma exerted a negative control on satellite cells to prevent proliferation. This inhibition was removed following structural damage.

Positive control was also suggested by Bischoff (1990) through the action of mitogenic factors, the nature of which are as yet unclear (Lieber, 1992).

Regeneration subsequently follows the normal pattern of muscle development; satellite cells align themselves along the basal lamina and fuse into myotubes. The presence of the basal lamina appears to influence this process, providing a substrate upon which alignment can occur and expressing a number of extracellular matrix components. It is not, however, essential to the process, reduced levels of regeneration occurring in the absence of an intact lamina (Vandenberg, 1982; Gutali et al, 1983).

As the myotubules mature and differentiate, they synthesis myofibrillar proteins and deposit them in the outer subsarcolemmal region. As the fibres fill with contractile protein, the muscle nuclei are normally pushed to the periphery, though a few may remain centrally as testimony to the repair process (Lieber, 1992).

CONCLUSION

Injury to soft tissue structures is detrimental to the well being and function of an individual, and open injuries may lead to the introduction of infecting organisms and further tissue damage. The rapid closure of open wounds and the accelerated healing of all lesions leads to a enhanced clinical outcome. Electrophysical agents such as ultrasound, shortwave diathermy and laser are advocated for the treatment of soft tissue injuries by a number of workers (Ohshiro and Calderhead, 1988; Low and Reed, 1990; Michlovitz, 1990).

Relatively little is known about the way in which these agents interact with soft tissue structures during the healing processes. This chapter examined the process of healing and considered specific differences in this process in relation to the different tissue types. The following chapters of the thesis will examine the way in which US, SWD and laser are thought to interact with the biological tissues, the physiological changes which these agents are thought to produce in the healing process and the evidence for their efficacy in clinical trials.

SECTION I. Chapter 5.

PHYSIOLOGICAL EFFECTS MEDIATED BY ULTRASOUND, SHORTWAVE DIATHERMY AND LASER IN THE REPAIR OF SOFT TISSUE LESIONS.

A clear understanding of the physiological effects which arise as a result of the application of ultrasound (US), shortwave diathermy (SWD) or laser is essential to the physiotherapist who is selecting treatment to assist healing of soft tissue lesions. The evidence available to substantiate the claimed effects will be discussed in this chapter. The effects discussed here relate closely to both the physical properties of each medium and their behaviour within the tissues, already discussed in chapters 2 and 3.

Physiological effects may be studied through the use of cell studies, animal studies (both *in vitro* and *in vivo*) and normal human investigations. Clinical efficacy must, however, be ultimately studied through the use of rigorous and ethically designed clinical trials. Cell studies provide the opportunity to investigate the basic mechanisms occurring at cellular and tissue level whilst animal studies allow investigations which are precluded by ethical considerations from human studies. The information gained from such work provides a theoretical basis for clinical practice and information upon which to base the implementation of clinical trials.

Care must be taken in extrapolating from one type of study to another. Whilst cellular studies facilitate maximal control over the environment and treatment parameters, they may be over simplifications of the complex clinical situation in which treatment will ultimately be given. Again, animal studies allow complex, integrated physiological systems to be examined but, due to factors such as animal size and the healing characteristics of the species, results may not reflect clinical practice (Basford, 1986; 1989). Even normal human studies may not fully reflect the reactions of clinical subjects; both Karu (1988) and St einlechner and Dyson (1993) report that damaged cells may be more responsive to electrophysical agents than normal cells.

This chapter will review the cellular, animal and normal human studies which have been conducted to investigate both the thermal and nonthermal effects of ultrasound, shortwave diathermy and laser on soft tissue lesions. The physiological effects occurring during the healing process may be due to either thermal or non-thermal effects of the electrophysical agent used in treatment; both will be considered in the following section. Whilst it is possible that both reactions may occur simultaneously in certain situations but they will be discussed separately to facilitate clarity.

THERMAL AGENTS: ULTRASOUND AND SHORTWAVE DIATHERMY

An increase in tissue temperature due to a variety of agents has been shown by many workers to affect the physiological behaviour of soft tissue structures (Gersten, 1955; Abramson et al, 1960a; 1960b; Harris and McCroskery, 1974). It has been suggested that therapeutic effects occur at a temperature of between 40-45^{0}C, provided that the temperature is maintained for at least 5 minutes (Guy et al, 1974; Delpizzo and Joyner, 1987).

Dyson (1987), Lehmann and de Lateur (1990), Michlovitz (1990) and Collins (1994) list the physiological effects which result from an increase in temperature in normal tissues. These include an increase in metabolic activity and altered chemical reactions (Lehmann et al, 1954; Abramson et al, 1958; Harris and McCroskery, 1974), an increase in blood flow (Bickford and Duff, 1953; Imig et al, 1954; Paul and Imig, 1955; Abramson et al, 1960a, b), a decrease in the viscosity of fluids (Michlovitz, 1990; Collins, 1994), increased extensibility of collagenous tissues (Gersten, 1955; Lehmann et al, 1970; Warren et al, 1971, 1976), decreased pain (Lehmann et al, 1958; Barbour et al, 1986; Kramer, 1984) and a decrease in muscle spasm (Lehmann and de Lateur, 1990). Prolonged heating of tissue can additionally result in altered tissue structures; Kligman (1982) demonstrating an increase in elastic fibres and ground substance in the skin of the guinea pig following extensive heating (skin surface temperature of 40°C, 15 minutes, three times a week, for 45 weeks) and Westerhoff et al (1987) stating that prolonged heating at a surface temperature of 42°C, over a period of hours, results in an alteration in the amino acid composition of proteins.

Discussion of the thermal effects of therapeutic ultrasound and shortwave diathermy dominated the early literature (Imig et al, 1954; Abramson et al, 1960a,b; Lehmann et al, 1966; Lehmann and Guy, 1972; Chan et al, 1973;

Hansen and Kristensen, 1973; Verrier et al, 1977; Lehmann et al, 1978) and a number of authors continue to explore this area (Sandler and Feingold, 1981; MacDonald and Shipster, 1981; Stoller et al, 1983; Black et al, 1984; Ward, 1986; Frizzell and Dunn, 1990). The physiological effects induced by heating have been examined using cell studies, animal models and normal human subjects.

The predominant physiological effects which are likely to benefit the repair of soft tissue lesions are an increase in metabolic activity and an increase in local circulation; these will be discussed at greater length. Whilst associated loss of function may be improved through the effect of heat on collagen extensibility, pain and local, (non-neurological) muscle spasm, these effects will not be addressed here.

Biochemical effects: A number of authors have shown that elevation of temperature affects chemical activity within cells; metabolic activity increases by two to three fold with every 10^0C rise in tissue temperature (Ganong, 1989; Lehmann and de Lateur, 1990). There is some evidence to suggest that this effect is only operant to a certain threshold level; above this value there is a gradual decline in activity.

Oxygen and food uptake by tissue increase and production of waste materials escalate with small temperature increases. Abramson et al (1958) demonstrated an increase in oxygen uptake by human muscle at intramuscular temperatures of between 28-38^0C whilst Lehmann and colleagues (1950; 1953; 1954) observed a decrease in metabolism of the diaphragm in the mouse at external temperatures of 46.5^{0}C.

Components of enzyme systems, such as proteins, are increasingly destroyed with temperatures above a threshold level. Harris and Krane (1973) and Harris and McCroskey (1974) examined the behaviour of collagenase at different temperatures; they demonstrated an increase in the enzyme with a rise in local temperature from 30^{0}C to 36^{0}C. Castor and Yaron (1976) showed an increase in the rate of hyaluronate synthesis and glycolysis in human synovial cell cultures with rises in temperature from 30^{0}C to 39^{0}C. Activity peaked at 38^{0}C, falling with rises to 41^{0}C.

Vascular effects: Both ultrasound and shortwave diathermy have been shown to give rise to an increase in local circulation. Many investigators have examined the vascular effects occurring following the application of ultrasound to tissue; some report increased blood flow (Bickford and Duff, 1953; Imig et al, 1954; Paul and Imig, 1955; Abramson et al, 1960a) and some decreased or unchanged flow (Bickford and Duff; 1953; Imig et al, 1954; Paaske et al, 1973; Wyper et al, 1978; du Raan et al, 1988). Doses and treatment protocols varied and methods of measurement differed, making it difficult to draw clear conclusions. Michlovitz (1990) suggests, in summary, that treatments of 10 to 20 minutes at 2 W/cm^2, 1 MHz, continuous wave are required to produce vascular changes, anything less being ineffective.

A number of studies have also demonstrated altered blood flow as a result of the application of both continuous and pulsed shortwave diathermy. Abramson et al (1960b) demonstrated increases, sometimes approaching double, in blood flow in their subjects following a 30 minute application of heat, whereas Hansen and Kristensen (1973) demonstrated smaller increases in flow when they applied the shortwave diathermy for a period of five minutes only. Both groups of investigators used doses which produced a subjective thermal response from the subject.

Both Wyper and McNiven (1976) and Millard (1961) demonstrated some increase in blood flow following the application of both continuous and pulsed shortwave diathermy but note it to be much less than could be produced by gentle or moderate exercise. Millard (1961) also compared the use of continuous diathermy (condenser field method, dosage set at maximum skin temperature tolerance for a 20 minute period) with gentle exercise. Temperatures and blood flow were measured in the skin, quadriceps muscle, tibialis anterior muscle and knee joint of normal human subjects. Results varied widely; the quadriceps muscle, the most vascular of the structures, showed greatest variability. Again Millard (1961) notes that any changes are small compared to the effects of 'a few minutes gentle exercise'.

With the use of treatment parameters which include the use of both high energy and pulsing levels, pulsed shortwave diathermy has been shown to produce increases in blood flow; Silverman and Pendleton (1968) demonstrated that both pulsed and continuous SWD produced equal changes in temperature and blood flow when the average power delivered was the same. Morrissey (1966) showed that at low average powers (40 watts) heating could not be demonstrated whereas higher average energy levels (80 watts) both tissue temperature and blood flow increased. This emphasises the need for full and accurate descriptions of parameters in trials; this is of particular importance when attempting to determine whether pulsed SWD is likely to have non-thermal effects.

Discussion:

It has been claimed that tissue heating can assist wound healing and result in increases in joint range, as well as temporarily reducing pain and muscle spasm (Venton-Gough, 1962; Patrick, 1978; Lehmann and de Lateur, 1990; Reed and Zarro, 1990); such claims are however, qualified by a number of authors. Lehmann and de Lateur (1990) and Michlovitz (1990) state that heat can produce an inflammatory reaction within tissues. In addition, the suggestion that increasing the blood supply to the area will increase the rate of healing may be controversial; while La Van and Hunt (1990) demonstrated that a defective blood supply will delay wound healing, Maxwell (1992) suggests that it is less certain that an increase will accelerate healing in otherwise healthy tissue.

Not all studies have demonstrated the efficacy of these agents in producing changes in physiological parameters. Imig et al (1954) was unable to show an increase in circulation following the application of ultrasound to the hind leg of the dog, using a dose of 0.5 W/cm^2 for 15 minutes. Similarly, du Raan et al (1988) found that US (1 MHz, 1.5 W/cm^2, continuous mode, 9 minutes) produced no changes in the local blood flow in the thigh.

Schmidt (1979) studied the effects of heat on acute and chronic inflammation in a rat model and reported that acute inflammation was aggravated by heat whereas chronic inflammation began to resolve. Basagoitia et al (1985) demonstrated that a combination of heat and cold significantly reduced experimental oedema in rats whilst Marek et al (1974) showed that the use of infrared irradiation in the acute phase of healing in experimentally induced lesions in the rat exacerbated the oedema.

Though traditionally advocated to aid the resorption of haematomas, evidence for the efficacy of heat treatment is again equivocal. While heating due to SWD was found by Fenn (1969) to aid the resorption of artificially induced haematomas in rabbit ears, Lehmann et al (1983) found that microwave diathermy had no effect on their resolution in pigs.

Bansal et al (1990) conducted a controlled trial to examine histological changes following the application of continuous SWD to surgically induced lesions in dogs. SWD was administered for five minutes daily from day two to eight at an 'intensity of bearable heat'. Tissue was excised for examination at day 15. When the tissue from treated and control lesions was compared, it was found that the collagen present at the treated site was of a relative more mature type and fewer fibroblasts were present. Control tissue contained atrophied and necrosed muscle fibres while normal muscle fibres were identified in tissue adjacent to the treated lesions.

The use of heat to enhance tissue healing is therefore not unequivocally supported by the literature; the treatment of subacute and chronic lesions may be advantageous but further work is needed to identify appropriate treatment protocols.

NON-THERMAL AGENTS: ULTRASOUND, SHORTWAVE DIATHERMY AND LASER

Ultrasound, shortwave diathermy and laser are used in physiotherapy practice to enhance the healing of soft tissue lesions in forms which are generally regarded by physiotherapists as nonthermal. US has been observed to have stimulative effects at dosages of between 0.1 and 0.2 W/cm^2 $I^{(SATA)}$, effects which are unlikely to be due to physiologically significant thermal changes (Dyson, 1990). Any effects produced by the use of pulsed SWD are still the subject of considerable controversy; Low and Reed (1990) intimate that 'all explanations advanced to explain the mechanisms of pulsed shortwave are entirely speculative'. Similarly, the effects of low level laser irradiations on tissue healing are still unclear; studies report contradictory results and doubt exists in the minds of some, such as Lehmann and de Lateur (1990), as to its clinical efficacy.

The process of healing has been described in chapter 4 of this thesis. A number of studies have been conducted to examine the effects of each of these agents on the different aspects of this process. The following section reviews the evidence for the efficacy of these agents in producing optimal wound healing. It should, however, be noted that no studies were found to substantiate the claimed nonthermal effects of pulsed SWD at the cellular level.

CELL STUDIES

Many of the *in vitro* studies which have examined the physiological effects of electrophysical agents have involved the use of human or animal cells; such studies have concentrated on examining the early stages of the repair, including both the inflammatory and proliferative phases of healing.

Inflammatory phase

Mast Cells: Some of the earliest changes in vessel permeability are due to histamine, which is released by mast cells; this has lead investigators to examine the behaviour of these cells following the administration of electrophysical agents. Fyfe and Chahl (1984), Dyson and Luke (1986) and Hashish (1986) found that mast cell degranulation occurred following the use of ultrasound. Dyson and Luke (1986) reported that doses of 1.5 W/cm^2 $I^{(SATA)}$ (3 MHz; continuous mode) were required to achieve degranulation in intact skin and suggested that a thermal component might be necessary; Fyfe and Chahl

(1984) used lower doses (0.5 W/cm^2 $I(^{SAPA})$; 0.75, 1.5 and 3.0 MHz; pulse ratio 2:8) to achieve similar effects in injured tissue. Hashish (1986) found that doses of 0.1, 0.5 and 1.5 W/cm^2 $I^{(SAPA)}$ (3 MHz; pulsing ratio 1:4) were effective in inducing degranulation. These studies were confirmed by Byl et al (1992) who examined the effect of insonation (1.5 W/cm^2; 20% pulsing; 1 MHz) on mast cell degranulation during wound healing in Yucatan pigs.

A number of investigators have reported changes in mast cell behaviour following irradiation with laser. El Sayed and Dyson (1990) reported mast cell degranulation following the irradiation of cells with laser at an average energy density of 10.8 J/cm^2 and wavelengths of 660, 820, 940 and 950 nm. Trelles et al (1989) reported similar results, using a He–Ne laser, and found that the combination of parameters was important; a greater level of mast cell degranulation was found in mice following a short, high intensity dose than in those receiving a longer, lower intensity dose, though the total energy input was identical for both groups.

Macrophages: Macrophages phagocytose wound debris and elaborate many factors needed in the healing process (Clark, 1985); Young and Dyson (1990b) examined the effect of therapeutic levels of ultrasound (2.5 W/cm^2 $I^{(SAPA)}$; 0.75 and 3.0 MHz; pulsing ratio 1:4) on U937 cells (an unstimulated form of macrophage which can be maintained *in vitro*) and reported the release of factors into the supernatant, which, when added to fibroblasts, resulted in increased cell proliferation.

Laser has also been used to stimulate the action of macrophages; Bolton et al (1990; 1991; 1992), Young and colleagues (1988; 1991) and Zheng et al (1992) all report the activation of macrophage cells by laser of differing wavelengths, energy densities and power densities. Release of growth factors (Bolton et al, 1990; 1991; 1992) and the uptake of calcium (Young et al, 1991) have been studied and Zheng et al (1992) reported that the immune response of mouse macrophage cells appeared to be activated by laser. Again these investigators emphasise that dosage parameters appear to influence the final outcome.

Platelets: Williams (1974) demonstrated that ultrasound could cause the release of serotonin, a substance active in the initiation of secondary vasoconstriction in wound healing (Clark, 1991). Later studies suggested that US might, however, lead to platelet aggregation and possible vessel occlusion. Despite *in vitro* studies which suggest that therapeutic levels of US might give rise to platelet degranulation and possible aggregation (Williams et al, 1976a,b; Chater and Williams, 1977; Williams et al, 1978) *in vivo* studies, conducted by Williams (1985) and Chater and Williams (1982), were unable to demonstrate any platelet activation or damage.

Keratinocytes: Steinlechner and Dyson (1993) examined the effect of laser on these cells and reported that low level laser produced a significant increase in cell proliferation, even at very low intensities of 0.25 J/cm^2; the increase was most significant when the cell had been grown in poor conditions.

Calcium, potassium and sodium: Mast cell degranulation and fibroblast activity may be triggered by raised intracellular levels of Ca^{2+} (Yurt, 1981); treatment with ultrasound has led to increased levels of intracellular calcium in both types of cell (Mummery, 1978; Mortimer and Dyson, 1988; Dyson, 1985). Young and Dyson (1990b) noted increased calcium influx in macrophages treated with ultrasound and Karu (1991) reported the uptake of calcium ions by lymphyocytes following a single irradiation with He-Ne laser.

Chapman (1974) and Chapman et al (1979) demonstrated that insonation of rat thymocytes could alter cell permeability to potassium ions and Mortimer et al (1980) demonstrated changes in cell membrane permeability to sodium following insonation with therapeutic ultrasound.

ATP and RNA/DNA synthesis: Pasarella et al (1984; 1988), Nedelia et al (1985) and Karu (1988) report that the helium-neon laser increases the rate of ATP synthesis within cells; in addition RNA/DNA synthesis was increased in HeLa cells (Karu, 1987) and fibroblasts (Lyons et al, 1987) using laser energy.

Laser irradiation has also been shown to effect increased intracellular cyclic adenosine monophosphate (cAMP) levels (Karu, 1985; 1988), increased hydrogen ion concentration (Karu, 1988) and altered membrane potentials (Kubasova et al, 1984; Parassela et al, 1984).

Proliferative phase

Fibroblasts: In 1990, Young and Dyson examined the effects of ultrasound of different frequencies on fibroblasts; 0.75 MHz ultrasound (0.5 W/cm^2 I$^{(SATA)}$; pulsing ratio 1:4; five minutes) resulted in the liberation of preformed fibroblast affecting substances from U-937 cells whilst frequencies of 3.0 MHz appeared to stimulate the cell's ability to synthesise and secrete fibroblast mitogenic factors. Protein synthesis following the application of US to wounded tissue has been examined by a number of researchers; Popsilova and colleagues (1971; 1976) first reported increased synthesis following the stimulation of fibroblasts with US. Harvey et al (1975) reported the stimulation of fibroblast activity resulting in an increase in protein synthesis and Webster (1980) and Webster et al (1978; 1979) subsequently demonstrated increased protein synthesis following the use of dosages of 0.5 W/cm^2 I$^{(SAPA)}$.

Both Hardy et al (1967) and Parshad and Sandford (1977) suggested that fibroblast proliferation is increased by the application of laser; this was later confirmed by Boulton and Marshall (1986), Dyson and Young (1986) and Abergel et al (1987). Boulton and Marshall (1986) demonstrated a significant increase in numbers of fibroblasts following irradiation with a single dose from a 1 mW, pulsed He-Ne laser; they also reported that cell attachment to the substrate was increased in immature fibroblast cells. Rigau et al (1991) reported increased fibroblast proliferation and metabolism following laser irradiation with a He-Ne laser and Lubart et al

(1993) reported that fibroblast proliferation was significantly enhanced with the application of laser of 540 and 600-900 nm. Many of these researchers note that results appear to be energy and intensity dependent.

In contrast to these results, Hallman et al (1988) and Lam et al (1986) failed to demonstrate increases in fibroblast proliferation with the use of laser, though Lam et al (1986) reported an increase in the production of procollagen.

ANIMAL AND NORMAL HUMAN STUDIES

In addition to the *in vitro*, cellular work a number of studies have been conducted using a variety of animal models and normal human volunteers. These have often focused on the later stages of healing or on more generalised characteristics of lesions such as bruising or oedema. As the aspects examined have varied from one agent to another, each will be examined separately.

Ultrasound

Studies have been conducted which examine the effects of US on both animal and normal human models. Studies on animals have examined the effects of US on inflammation, bruising and oedema, angiogenesis and collagen repair. A single experimental study on normal human subjects examined the effect of US on acute inflammation.

Inflammatory process: Goddard et al (1983) implanted irritant sponges containing bacteria into rats, thus producing chronic inflammation of the soft tissues. Those lesions receiving US treatment were compared with those acting as controls. No difference in tissue response was found. This contrasts with more recent evidence (Young and Dyson, 1990a), also obtained in rats, which suggested that the inflammatory phase associated with surgically induced skin wounds can be accelerated, and with Dyson's earlier work on tissue regeneration, using rabbits, which showed an increased rate of regeneration following insonation (Dyson and Pond, 1970).

Snow and Johnson (1988) produced mild inflammation in the normal human model using ultraviolet rays and found no significant reduction in inflammation between the insonated and control patches.

Bruising and oedema: The effect of ultrasound on experimental bruising has been assessed by Hustler et al (1978) who reported more rapid resolution in the insonated group. Fyfe (1979) and Fyfe and Chahl (1984) found that oedema was reduced in rats in insonated groups both immediately (1979) or after an initial 48 hour period (1984), suggesting either an accelerated resolution or a reduction of acute inflammation.

Angiogenesis: Angiogenesis is vital to wound repair (Hunt and Dunphy, 1979) and factors which enhance this may well enhance wound healing (Young and Dyson, 1990c). The use of ultrasound to enhance angiogenesis has been examined by Hogan et al (1982) and Young and Dyson (1990c). Hogan et al (1982) reported the use of US of 1 MHz at 0.25, 0.5, 5.0 and 10 W/cm^2 (temporal average) on vessel lumen, volume flow and rate of vasomotion. No changes were reported at intensities below 5 W/cm^2; above this value there was decrease in all parameters. In contrast, a significant increase in angiogenesis was demonstrated by Young and Dyson (1990c) following insonation of wounds with US at 0.1 W/cm^2 SATA; 0.75 MHz; a smaller increase was also demonstrated in wounds treated with a similar dose but at a frequency of 3 MHz.

Repair of collagenous tissue: Shamberger et al (1981) examined the behaviour of collagenous tissue in wound healing and showed a decrease in the tensile strength of wounds, in rats, following insonation. This work reflected the results of earlier work by Popspisilova and Rottova (1977). Similarly, Roberts et al (1982) applied pulsed ultrasound, 0.8 W/cm^2 (no indication is given as to whether this is the temporal peak or temporal average value) and frequency of 1.1 MHz, to severed tendons in an animal model, for five minutes, five times a week for six weeks. He found that those that were insonated did not heal at all whilst the controls showed normal healing.

In contrast, both Dyson (1981) and Drastichova et al (1973) demonstrate an increase in the tensile strength of collagen during the remodelling phase of wound healing when lesions were treated with ultrasound. This was confirmed by Enwemeka (1989), who examined the tensile strength and energy absorption capacity of surgically excised rabbit tendon after nine days treatment with US (1 MHz; 1 W/cm^2, continuous beam, five minutes daily) and reported that both measures were increased in comparison to the control lesions. Finally, Jackson et al (1991) demonstrated increased protein synthesis in healing achilles tendon following the application of US, the rate of repair being greater in those treated, and Byl et al (1992) reported an increase in collagen deposition and its tensile strength in surgical lesions in Yucatan pigs following insonation.

Pulsed shortwave diathermy

Pulsed shortwave diathermy can be used in such a way as to produce no perceptible thermal changes and for this reason studies using this from of energy are considered in this section; some trials reported here may, however, have employed doses which gave rise to thermal changes, though this is not always known. A limited number of animal studies have been conducted, looking at the efficacy of pulsed SWD on tissue lesions of different types. Results have been mixed.

Cameron (1961) conducted a controlled trial to evaluated the effect of pulsed SWD on healing wounds in dogs and noted that healing, at a cellular level, was more advanced in those receiving treatment. Fenn (1969) examined the effects of 'Diapulse' on chemically induced haematomas in the ears of rabbits and found that resolution was accelerated in those animals receiving active treatment. Details of dosage are however poorly defined in this paper, a penetration setting of '4' on the diapulse being indicated. Raji (1984) conducted a double blind trial, evaluating the efficacy of a pulsed electromagnetic field (PEMF) in accelerating the recovery of sectioned common peroneal nerves in rats; full details of surgical procedure, care and the assessment of regeneration are given. Animals treated with PEMF (pulse frequency 400; diapulse 4, peak power) showed faster recovery than the controlled, placebo treated group, both in terms of function and histological analysis, values being statistically significant.

Other workers have been unable to provide evidence of the efficacy of pulsed SWD in animal experiments; Brown and Baker (1987) created muscle injuries in 32 rabbits by means of injection with Xylocaine [R]. Half the animals were treated with pulsed SWD, and treatment parameters were varied during the course of the treatment in line with the suggestions of the manufacturers of the machine (250 W Megnatherm machine). No statistically significant difference was seen in the histological condition of the lesions at 8 or 16 days. The latter result was despite the fact that subjective assessment suggested that those animals treated demonstrated slightly better healing levels. This result confirmed the work of Constable et al (1971) who were unable to demonstrate any difference in the tensile strength of healing wounds in guinea pigs treated with pulsed SWD when compared with controls. Krag et al (1979) confirmed this view through the evaluation of the effect of pulsed SWD on the healing on experimental skin flaps in rats in a double blind, controlled trial. Full details of procedure and dosage are given. At seven days post surgery the animals were sacrificed; no statistical difference was found between the two groups in terms of microcirculation, which would be expected to influence the survival of the flaps.

Laser

The effect of laser on soft tissue lesions has been examined through the use of surgical lesions (Surinchak et al, 1983; Jongsma et al, 1983; Hunter et al, 1984; Cummings, 1985; McCaughan et al, 1985; Dyson and Young, 1986; Basford et al, 1986a, 1986b; Anneroth et al, 1988; Mester and Mester, 1989) and burn wounds (Trelles, 1988; Rochkind et al, 1989; Sasaki et al, 1992). Herman et al (1987) has additionally demonstrated laser induced healing of cartilage. Most experiments have used small, loose skinned animals, though a few have used the pig.

Accelerated healing: Cummings (1985) reported accelerated wound healing following the irradiation of surgical wounds in rats; a helium-neon (He-Ne) laser was used but no details of dose were given. Dyson and Young (1986) irradiated full thickness wounds in rats with combined He-Ne and infrared (IR) laser at frequencies of 700 Hz and 1200 Hz; by day 11 there was a significant increase in cellularity in those treated with the 700 Hz laser, fibroblast cells predominating. Sasaki et al (1992) demonstrated superior burn wound healing in rats following irradiation with 830 nm, 60 mw, continuous wave LLLT when compared with sham irradiated and control groups.

Other workers failed to report acceleratory effects; Jongsma et al (1983) used the argon laser to treat skin wounds in rats; Surinchak et al (1983) used the He-Ne laser to treat surgical lesions in rabbits and McCaughan et al (1985) treated wounds in guinea pigs with the argon laser. All of these workers describe different dosage parameters from one another and some give incomplete details. None, however, reported any effects from LLLT.

A few experiments have been reported using the pig, an animal with tissue characteristics and dimensions closer to that of human subjects; Hunter et al (1984) and Basford et al (1986b) conducted studies of wound healing, using helium-neon lasers. Hunter et al (1984) evaluated the effect of LLLT by measuring the percentage of wound healing over a period of time and Basford et al (1986b) monitored effects by assessing time to wound closure, wound strength and bacterial colonisation. Neither worker reported finding any benefit from LLLT.

Angiogenesis: Hickman and Dyson (1988) and Ghali and Dyson (1992) demonstrated an increase in angiogenesis following irradiation of wounds in rats. Hickman and Dyson (1988) used combined infrared and He-Ne laser to treat full thickness skin lesions. Those lesions irradiated showed increased capillary invasion compared with the control wounds. Ghali and Dyson (1992) stated that light at a wavelength of 660 nm and energy density of 4 J/cm^2 was significantly effective while a dose of 820 nm and 2 J/cm^2 was ineffective, suggesting important dose dependent characteristics.

Repair of collagenous tissue: Glassberg et al (1988) exposed wounds in mice to LLLT (no details of dosage) for two months and found that total collagen content was greater than in the control group at the end of this period. The effect of laser treatment on wound breaking strength has also been examined by a number of workers; Surinchak et al (1983) reported that doses of 2.2 J/cm^2 for three minutes twice daily for 14 days, using a He-Ne laser, produced a 55% increase in wound breaking strength whilst doses above and below this value failed to do so.

Glassberg et al (1988), on the other hand, again using a helium-neon laser found that procollagen levels were increased by up to 6.5 fold in the irradiated pig when compared with control animals.

Wound contraction: Dyson and Young (1986) irradiated full thickness wounds in rats with combined He-Ne and IR laser at frequencies of 700 Hz and 1200 Hz and reported increased wound contraction in lesions irradiated with the 700 Hz laser; this corresponded with the wounds containing the greatest number of fibroblasts. Lee et al (1993) showed that infrared laser speeded up the closure of infected wounds in rats.

Many other studies have taken place on animals (Kana et al, 1981; Haina et al, 1982; Abergel et al, 1987; Longo et al, 1987; Trelles, 1988; Baverman et al, 1989; Hubacek et al, 1989; Jun-Ying, 1992 and others). The results of these studies have been mixed; the parameters used are varied and reporting not always complete, and the variables measured have been diverse, included tissue tensile strength, collagen and procollagen content of the wound, angiogenesis, time to wound closure, wound contraction and the cellular content of the wound bed.

Discussion

As demonstrated above, not all investigators have been able to confirm the efficacy of ultrasound, pulsed shortwave diathermy and laser in the management of soft tissue lesions. Many factors have been identified in their reports which may contribute to the variation in the results seen. These factors may include diversity in wavelength, intensity, duration of treatment and chronicity of the wound at the time of treatment.

Many of these studies vary in the parameters they measure, the treatment protocols used and the types of lesions created. Details of dosage and procedures are not always complete. Thus care must be taken when drawing conclusions from the data presented; negative results could result from inappropriate protocols but at present there is no evidence for this.

Wavelength has been shown to be an important factor in determining trial results in studies of both US and laser; Young and Dyson (1990a) showed that the application of US at frequencies of 0.75 MHz and 3 MHz led to significant differences in cell counts in experimental tissue lesions; the number of polymorphonuclear leucocytes were lower in the 0.75 MHz group than in the control group and the 3 MHz group and the numbers of endothelial cells were lower in the 3 MHz group when compared to the other two. Similarly, laser appears to be wavelength specific; different cell types may respond optimally to different laser wavelengths (Agaiby and Dyson, 1990; El Sayed and Dyson, 1990; Steinlechner and Dyson, 1990) and individual cells, such as macrophages, may respond to specific frequency windows (Young et al, 1991).

Both ultrasound and laser may be pulsed, and evidence suggests that the frequency at which this occurs may also give rise to variation in tissue response (Low, 1978; Muller, 1983; Dyson and Young, 1986). Though SWD is also pulsed, there is currently no evidence to suggest that the pulsing ratio affect results; there is, however, no reason to believe that this agent will prove to be different from the others in this respect.

The level of chronicity of a wound may modify its response to sound and light (Dyson, 1990: Karu, 1988). Snow and Johnson (1988) reported no effect from the use of US to treat an acute inflammatory reaction where as others have demonstrated clinical effects with respect to chronic lesions (McDiarmid et al, 1985). Karu (1988) showed that light stimulates cells which are proliferating at a submaximal level and suggests that 'stimulation by light may take place only when the culture growth rate is slow'. Similarly, St einlechner and Dyson (1993) reported that cells grown in poor conditions responded more vigorously to laser therapy. Thus fresh, experimental wounds which are likely to be repairing at an optimal level may show no response to ultrasound or laser.

Finally, both ultrasound and LLLT of a specific wavelength have been shown to have both acceleratory and inhibitory effects on tissues, higher doses producing damage and lower doses possibly being ineffective (Dyson, 1989; Karu, 1988; Ohshiro and Calderhead, 1988). Dyson (1989; 1990) suggests that ultrasound can be pro-inflammatory if given at too high a dose whist Karu (1988) and Ohshiro and Calderhead (1988) suggest that laser intensities in the region of 7 J/cm^2 may lead to cell inhibition and possibly death.

SECTION I. Chapter 6

CLINICAL EFFICACY OF ULTRASOUND, SHORTWAVE DIATHERMY AND LASER IN PATIENTS WITH SOFT TISSUE LESIONS.

The studies described in chapter 5 of this thesis provide invaluable guidelines upon which to base the more complex and ethically demanding clinical trials reviewed in this section, trials which are essential to determine the efficacy of electrophysical treatments in the target populations. Those pertaining to each agent will be examined separately.

Ultrasound

Both thermal and nonthermal levels of ultrasound are claimed to facilitate the optimal healing of soft tissue lesions, and their efficacy in this respect has been examined by a number of researchers.

Though both types of treatment may be given, many studies do not provide adequate information about dosages to enable the reader to judge whether the treatment was given at a thermal or subthermal level. It is therefore suggested that, for the purposes of this review, intensities of 1.0 to 2.0 W/cm^2, continuous beam for 5 to 10 minutes or more are likely to have resulted in perceptible heat production (Ziskin et al, 1990). Lesser intensities may be more likely to allow nonthermal effects to dominate.

The clinical efficacy of ultrasound has been examined in relation to a wide variety of soft tissue lesions including open wounds, muscle, tendon and ligament injuries and bursal lesions. However, despite an apparently extensive list, each subject is represented by a small number of papers, frequently no more than two or three, and not all studies confirm the efficacy of ultrasound.

A number of papers, dating from 1960 on, have been examined in detail. Most studies were found to address injuries of one of three types; these were (1) tendon and ligament injuries, (2) acute inflammatory lesions and (3) skin lesions associate with vascular deficiencies. In order to facilitate both clarity and comparison between the studies, details of these studies are presented in tables 2 to 4. The numbers of subjects, use of randomization, the number of treatment groups, the ultrasound dosages, any additional treatments and outcome are noted.

The results of these studies suggest that a wide variety of dosages have been used in the evaluation of ultrasound and that outcomes have varied. Two thirds of the studies considered in these tables support the view that ultrasound can produce significant beneficial effects, though the remaining studies fail to do so. However, an examination of the dosage parameters reported provides little indication of the parameters which are most likely to be successful, though Hashish et al (1986) suggest that low doses are most effective. A number of studies reported that treatment with ultrasound was no more effective than the use of placebo, though both were more effective

TABLE 2. ULTRASOUND: EVIDENCE OF EFFICACY IN THE MANAGEMENT OF SOFT TISSUE LESIONS

TENDON AND LIGAMENT INJURIES

CONDITIONS	AUTHORS	RANDOM	N	TREATMENT GROUPS	US DOSAGES	No of Trs.	RESULTS
Lateral epicondylitis	Binder et al., 1985	Yes	38	1. US	1 MHz, 1 4, --- 5-10 mins	12	US superior to sham US
			38	2 Sham US	---	12	
	Lundeberg et al., 1988	Yes	33	1 US	1 MHz, C, 1W cm' 5-10 mins	10	US and sham US superior to rest
			33	2 Sham US	---	10	
			33	3 Rest	---	---	
	Haker and Lundeberg, 1991	Yes	21	1. US	1MHz P, 1W cm² 10 mins	10	No difference between groups
			21	2 Sham US	---	10	
Ankle ligament injuries	Makuloluwe and Mousas, 1977	Yes	40	1 US + ice	0 1/1 MHz, -, 1 5W cm² 4 mins	4-6	US + ice superior to immobilization
			40	2 Immobilization	---	---	
	Williamson et al., 1986	Yes	80	1 US + Ex + ice	No detail	---	No difference between groups
			74	2 Sham US + Ex + ice	---	---	

Key US - ultrasound, Ex - exercise, Tr s - treatment/s, N - number of subjects, P - pu cd beam US, C - cont nuou bea US

TABLE 3. ULTRASOUND: EVIDENCE OF EFFICACY IN THE MANAGEMENT OF SOFT TISSUE LESIONS

ACUTE INFLAMMATORY LESIONS

CONDITIONS	AUTHORS	RANDOM	N	TREATMENT GROUPS	US DOSAGES	No of Trs.	RESULTS
Oral Surgery	El Hag et al., 1985	Yes	33	1 US	30 MHz, 1.4; 0 5W/cm² 8 mins	2	Reduced swelling and trismus with trs 1 & 2
				2 Dexamethasone	---		
				3 Control	---		
	Hashish et al., 1986	Yes	50	1 Control	---		Trs 2-5 reduced pain, swelling and trismus Low doses most effect Placebo similar to trs 4 & 5
			25	2 Sham US	---		
			25	3. Rest	3 MHz, 1 4; 0 1W/cm²	1	
			25	4 US	3 MHz, 1 4, 0 5W cm²	1	
			25	5 US	3 MHz, 1 4 1 5W/cm² - all at 5 mins	1	
	Hashish et al., 1988	Yes	25	1. Control	---		Maximum benefit in group 4, effect considered placebo
			25	2 US	3MHz; 1 4; 0.1W/cm²	1	
			25	3. Sham US + massage	Sham US + head moving	1	
		Yes	25	4 Sham US	Sham US, head still	1	
			25	5 Self-massage	Circular finger massage - all at 5 mins	1	
Peroneal trauma	Creates, 1987	Yes	39	1. US	Varied according to lesion	---	Pain less following treatment with US
			37	2 Sham US	---	---	

	Grant et al., 1989	Yes	135	1. PEME	---	up to 3	No difference between groups, 90% felt better
			140	2 US	3 MHz, 1 4, 0 5W cm² 2 mins per probe head area	up to 3	
			[illegible]	[illegible]			

Key US - ultrasound, Ex - exercise, Tr s - treatment/s, N - number of subjects, P - pulsed beam US, C - continuous beam US

TABLE 4. ULTRASOUND: EVIDENCE OF EFFICACY IN THE MANAGEMENT OF SOFT TISSUE LESIONS

SKIN LESIONS

CONDITIONS	AUTHORS	RANDOM	N	TREATMENT GROUPS	US DOSAGES	No of Trs	RESULTS
Ulcers	Dyson and Suckling, 1978	Yes	12	1 Sham US	---		US superior to sham
			12	2 US	3MHz, 2 8, 0 2W cm (TASA), 5-10 mins	up to 12	
	Dyson and Suckling, 1978	No (sequential)	7	1 Sham US - then	---		US superior to sham
				2 Sham	3MHz, 2 8, 0 2W cm (TASA), 5-10 mins	up to 12	
	Oakley, 1982	No	1	1 US	Varied with stage of healing	approx 7-8 months	Lesion healed
	Roche and West 1984	Yes	15	1 US	3MHz, 1 4, 1W cm 5-10 mins	12	US superior to sham
			15	2 Sham US	---	12	
	Callam et al, 1987	Yes	56	1 Standard tr	---	up to 12	US 20% better healing rate than standard tr
			52	2 Standard tr + US	1MHz, P, 0 5W cm 1 min per probe head area	up to 12	
	Lundeburg et al., 1990	Yes	22	1 Standard tr + sham US	---	24	No significant difference
			22	2 Standard tr + US	1MHz, 1 9, 0 5W cm 10 mins	24	
	Ericssons et al 1991	Yes	19	1 Standard tr + sham US		16	No significant difference between groups
			19	2 Standard tr + US	1MHz, C, 1W cm 10 mins	16	
Pressure sores	McDiarmid et al., 1985	Yes	21	1 US	3MHz, 1 1, 0 8W cm 5-10 mins	3x wk to healing	Significant improvement in dirty sores
			19	2 Sham US	Sham US		

Key US - ultrasound, Ex - exercise, Tr s - treatment/s, N - number of subjects, P - pulsed beam US, C - continuous beam US than no intervention (Hashish et al, 1986; Lundeberg et al, 1988; Grant et al, 1989). Other studies, however, such as those by Binder et al (1985) and Dyson and Suckling (1978) showed that active ultrasound was superior to sham irradiation. Again the differences do not appear to relate to dosage parameters or the lesions treated.

In additional to these studies, others have reported work to evaluate the effects of ultrasound in other situations. Inaba and Piorkowski (1972) used ultrasound to treat inflammatory shoulder problems accompanying hemiplegia; three groups received either (1) exercise, (2) ultrasound and exercise or (3) sham ultrasound and exercise. The researchers evaluated outcome through measurement of range of movement; they reported no differences between the groups at the end of the interventions. A similar type of study was conducted by Hamer and Kirk (1976) who compared the effects of ice with those of ultrasound on pain and range of movement in subjects with frozen shoulder syndrome. Again, they showed that there were no differences between the two groups. In contrast, a study of subjects with tenosynovitis, which used strength tests to evaluate outcome, suggested that the condition responded better to ultrasound and infrared irradiation than frictions and infrared (Lanfear and Clarke, 1972).

Both Gorkiewicz (1984) and Downing and Weinstein (1986) examined the effect of treating subacromial bursitis with mild thermal doses of ultrasound; Gorkiewicz (1984) treated a single subject with ultrasound (1 MHz; continuous; 1.5 W/cm^2) for eight minutes five days a week; the patient regained movement and pain was reduced. However, ultrasound treatment was augmented by exercise and manipulation and it appears that the bursa ruptured during treatment, making this an inconclusive report. Downing and Weinstein (1986), again treating subacromial bursitis, employed two subject groups; one received treatment comprising a standard treatment package (exercise plus non-steroidal anti-inflammatory drugs) plus active ultrasound (1 MHz; 1.2-1.3 W/cm^2) whilst the other received the standard package plus placebo ultrasound. No difference was seen between the two groups in terms of range, pain or function.

A number of studies have reported the use of ultrasound to treat breast engorgement, making use of thermal dosages (Shellshear, 1881; Semmler, 1982; McLachlan et al, 1991). Shellshear (1981) provided anecdotal evidence of clinical efficacy whilst Semmler (1982) provided limited but confirmatory evidence. McLachlan et al (1992) subsequently conducted a randomised, double blind, placebo controlled trial to examine the effect of ultrasound on the resolution of breast engorgement involving 197 cases. Ultrasound treatment was adjusted to provide a 'comfortable warmth' whilst the placebo treatment was modified to provide surface heating only. Under these conditions no significant difference was seen between the two groups, though both demonstrated subjective changes in pain and tissue hardness.

Shortwave diathermy

The clinical efficacy of thermal doses of SWD has been examined by a number of workers. However, relatively few studies have examined its effects on soft tissue lesions, the majority of studies having considered its effects on the arthropathies (for example, Harris, 1963; Wagstaff et al, 1986; Svarcova et al, 1988). Three studies were identified which indicated clearly that thermal doses were being employed to treat soft tissue problems. In 1939, Krusen and Elkins reported that cultures taken from 37 subjects with chronic pelvic inflammatory disease frequently became negative following treatment with a thermal dose of SWD; an 86% success rate was reported. Later Pasila et al (1978) reported that heat, produced by pulsed SWD, reduced swelling in subacute foot sprains. In contrast, Feibel and Fast (1976) demonstrated that heat exacerbated oedema production and prolonged recovery time in acute orthopaedic injuries. These studies reinforce the view that heat may exacerbate the inflammatory process in acute lesions whilst aiding healing in subacute injuries.

The following studies all employed pulsed shortwave diathermy as an active agent; however it is unclear from the information provided whether the dosage parameters were such as to allow thermal changes to be perceived by the patients.

Wilson (1972) compared the effect of pulsed SWD and sham treatment on pain, swelling and disability in subjects with inversion injuries of the ankle; he reported that the pulsed agent was significantly more effective than the sham. Similar studies in 1974 examined matched pairs, randomly allocated to one of two groups, but on this occasion Wilson (1974) compared the use of pulsed and continuous SWD. Continuous SWD was delivered for two 15 minute periods within the hour, once daily, whilst pulsed energy was given for one hour daily. Both groups also received a baseline treatment consisting of exercises and walking instruction. Those receiving pulsed energy displayed greater improvement (82.8%) in terms of swelling, pain and disability than those in the continuous SWD group (44.2%).

Wilson (1974) highlighted what he believed to be the primary difference between the two treatment regimens, this being the total power delivered; continuous SWD resulted in 22.5 watt-hours energy being received whilst those on the pulsed programme received 15 watt-hours. He notes that greater improvement occurred using the lower energy transmission and suggests that this may indicate that pulsed energy acts in ways other than through heating.

Both bursitis and ligament injuries have been treated with pulsed shortwave diathermy (PSWD). Ginsberg (1961) used pulsed SWD (pulse duration 65 microseconds, rests 1665 microseconds and average power 40 watts) in the treatment of 94 cases of calcification in bursitis; 80% of patients experienced symptomatic relief and 42 of the 46 cases subjected to X-rays before and after treatment showed signs of resorption.

Barclay et al (1983) evaluated the use of pulse energy on 230 patients with a variety of hand injuries, randomly allocated to either treatment or non-treatment groups. Swelling, disability and pain were assessed. Dosage parameters are given in full (65 microsecond pulse duration, 1,600 microsecond rest phases, 975 watt peak power, estimated to receive about 4 watt total energy). Those treated showing greater improvement than the untreated group, especially with respect to the parameter of swelling; this had marked effects on the pain experienced and the function demonstrated.

Acute lesions have also been treated with pulsed shortwave diathermy and a number of studies have examined its effects on the process of repair following surgical procedures. Kaplan and Weinstock (1968) conducted a double blind, controlled trial to evaluate the effect of pulsed SWD on post surgical oedema following foot surgery and reported that those receiving treatment demonstrated less pain and oedema than the control group. A randomised, controlled trial of boys undergoing orchidopexy demonstrated that the resolution of bruising and swelling occurred more rapidly in those receiving PSWD (Bentall and Eckstein, 1975). Aronofsky (1971) reported that levels of healing in surgical wounds following a variety of types of oral surgery improved following the use of pulsed SWD. Details of dosage (pulse length 65 micro seconds, pulse frequency 600, peak power 975 watts, average power 38 watts), length and frequency of treatment are given and a control group incorporated into the design. He evaluated the level of inflammation, pain and the rate of wound closure, relying on clinical experience to make judgements. Nicolle and Bentall (1982) produced similar results following bilateral blepharoplasty; 21 consecutive patients were treated unilaterally with pulsed SWD (1,000 pulses per second, 100 microseconds pulse duration). Nineteen subjects showed significant benefit in terms of reduced levels of swelling and inflammation on the treated side. Finally, Goldin et al (1981) examined the healing of grafts in a controlled trial. The parameters were given as peak output 975 watts, 400 pulses per second, pulse duration 65 microseconds, mean energy output 25.3 watts. Healing was evaluated at seven days and pain monitored during the period of treatment. Healing in those receiving active treatment was more advanced. There is no discussion about the pain measurements.

However, not all results have been so encouraging; Pasila et al (1978), Barker et al (1985), McGill (1988) and Grant et al (1989) were unable to support the view that pulsed energy was effective in assisting healing. Both Pasila et al (1978) and McGill (1988) examined subjects with ankle sprains and found no significant difference between those receiving active pulsed SWD or a placebo treatment. Barker et al (1985) examined 73 patients with damage to the lateral ligament of the ankle in a randomised, controlled trial. Some treatment parameters and a full description of the clinical protocol and assessment are given. No other active physiotherapy treatment was given. However, those who were thought to need such management were withdrawn from the study after three days; this will undoubtedly have affected the results, but ethical issues concerned the authors. No difference was found between those receiving either the active or placebo treatment but these results must be viewed with caution in the light of the limited information given about the dosage parameters used and the withdrawal of certain subjects from the trial.

Grant et al (1989) evaluated the effects of electrotherapy on the repair of peroneal trauma following child birth, comparing ultrasound and pulsed electromagnetic energy. Patients were randomly allocated to either of these treatments or to matched placebo groups. The parameters given included frequency and duration (27 MHz, 100 pulses per sec, 65 microsecond pulse width, duration 10 minutes) but not intensity or power. Pain and healing were assessed immediately after treatment, at 10 days and after three months. Ninety percent of all women, including those in the placebo group, felt that the treatment had helped; there were, however, no objective differences between any of the groups.

Finally, Livesley et al (1992) examined the use of pulsed SWD in the treatment of minimally displaced fractures of the neck of the humerus in a randomised, controlled trial. Treatment parameters are described and include pulse frequency of 35 and a peak power of 300 watts. Intensity is given in terms of the Curapuls machine, 'intensity level 3' being indicated. Both groups additionally received standardised physiotherapy treatment. No significant difference was found between the placebo and active treatment groups.

Differences in treatment parameters and protocols, though not excessive, may account for the diversity of results obtained by these workers. A comparison of the different parameters used by researchers examining the efficacy of pulsed SWD in given in table 4. It can be seen from this table that, in many instances, the information given is deficient; despite this it is clear that there are no outstanding differences between the protocols which were deemed effective and those found to be ineffective.

TABLE 5. PULSED SHORTWAVE DIATHERMY: DOSAGE PARAMTERS USED IN CLINICAL TRIALS

Name	Year	Condition treated	Length of treat-ment	Frequency	Peak power Watts	Average power Watts	Pulse length micro-seconds	Pulse frequency per second	Rest time micro-seconds	Other details
Pulsed SWD effective										
Ginsberg	1961	Bursitis	10 mins	-	1025	40	65	600	1665	Add lower dose to liver and adrenals Number of visits max appears to be 34.
Aronofsky	1971	Surgical wound	15 mins 10 mins 10 mins All 10 mins	24 hr before surgery Pre op Post op Then at 24, 48 & 72 hrs	975	38	65	600	N/A	
Wilson	1974	Inversion injury of ankle	60 mins	Daily for 3 days	975	-	65	NA	1600	
Bentall & Eckstein	1975	Orchidopexy	20 mins	3 x daily 4 days	-	-	-	500		Dose: penetrate level 5 Dipulse added lower dose for 10 mins to epigastrium
Goldin et al	1981	Skin grafts	30 mins	1 pre op then 6 hourly for 7 days	975	25.3	65	400	N/A	

TABLE 5. (continued)

Name	Year	Condition treated	Length of treat-ment	Frequency	Peak power Watts	Average power Watts	Pulse length micro-seconds	Pulse frequency per second	Rest time micro-seconds	Other details
Pulsed SWD effective (cont)										
Nicolle & Bentall	1982	Blepharoplasty	continuous	24 hours	-	-	100	1000	N/A	
Barclay et al	1983	Hand injuries	2 x 30 mins	Daily to discharge	975	>4	65	N/A	1600	
Pulsed SWD ineffective										
Pasila et al	1978	Ankle and foot sprains	20 mins	Daily for 3 days	-	38* 40**	-	-	-	*Diapulse **Curapuls
Barker et al	1985	Lateral ligament injuries	45 mins	Daily for 3 days	-	-	-	640	-	Therafield beta: intensity setting "high".
Grant et al	1989	Peroneal trauma	10 mins	Max of 3 trs. in 36 hrs	-	-	65	100	-	
McGill	1989	Ankle sprains	3 x 15 mins	3 consec days	-	19.6	-	82	-	
Livesley et al	1991	Fracture head of humerus	30 mins	Daily for 10 days	300	-	-	35	-	Intensity 3 Curapuls

Laser

Laser is used as a nonthermal agent only in physiotherapy practice. A variety of clinical trials have examined its efficacy in the management of both open and closed soft tissue injuries.

The majority of clinical reports concerning the use of laser to produce optimal tissue healing involve the management of chronic tissue damage. Both chronic wounds (Kahn, 1984; Mester et al, 1985; Gogia et al, 1988) and venous ulcers (Mester et al, 1985; Bihari and Mester, 1989; Mester and Mester, 1989; Jun-Ying, 1992) have been studied. Kahn (1984) presents two case studies in which He-Ne laser was used to treat large, chronic open wounds with beneficial results and Gogia et al (1988) describe two patients, again with chronic wounds, in which healing was achieved using an infrared laser in conjunction with whirlpool treatment. Mester et al (1985) and Mester and Mester (1989) describe their experience of the use of laser to treat chronic lesions, including non-healing open wounds and venous ulcers, using either He-Ne or argon laser (twice weekly; average intensity 4 J/cm^2). They concluded that laser was an effective form of treatment as they obtained healing rates of between 65% and 74% respectively over periods of 12 to 16 weeks.

Goujon et al (1985), Crous and Malherbe (1988), Bihari and Mester (1989) and Jun-Ying (1992) all claim some degree of success when comparing the state of ulcers before and after treatment with laser. Jun-Ying (1992), for example, reported that laser was beneficial in the management of ulcers; he treated 160 ulcers with He-Ne irradiation and reported increased healing rates in the treated group (73%) when compared to the control group (43%). In contrast, neither Santoianni et al (1984), using a He-Ne laser at dosages of 1 and 4 J/cm^2, or Brunner et al (1986) reported any benefit from irradiation.

The effect of laser on closed soft tissue lesions of various types has also been described, with a number of studies examining the effects of laser on the healing of collagenous tissues such as tendons and ligaments. In a study by Lundeberg et al (1987) tennis elbow failed to respond well to treatment; details of dosage and method (using acupuncture points) are full. This verdict was confirmed by Haker and Lundeberg (1990) when studying lateral epicondylagia, using an infrared laser. However, other researchers have reported contrary results; Vasseljen et al (1992) compared the effect of GaAs laser and placebo on tennis elbow. All patients received eight treatments and were later compared for pain and grip strength. Those receiving treatment were significantly better than those receiving the placebo, though these researchers note that laser as a sole treatment agent was of limited value and recommend further work comparing different active treatments. This Vasseljen (1992) did; he compared GaAs laser with 'traditional physiotherapy' (ultrasound and frictions) and demonstrated that both treatments resulted in an increase in grip strength and decrease in pain, though traditional therapy was more effective than LLLT in reducing the pain. Both England et al (1989) and Siebert et al

(1987) treated tendinopathies with laser; results were contradictory, the first reporting positive findings and the second negative. Finally, Meier and Kerkour (1988) examined the effects of He-Ne laser (0.17 J/cm^2) on patella and achilles tendons and reported no benefit from active treatment.

Lateral ligament injuries of the ankle have also been treated with laser. Kumar et al (1989) compared 'conventional physiotherapy' with the same package plus LLLT in the management of inversion injuries of the ankle; the use of LLLT resulted in less pain and swelling and an earlier return to weight bearing. Such a result was confirmed by de Bie et al (1989) who compared (1) active LLLT (IR laser, 0.35 J/cm^2) plus strapping, (2) placebo LLLT plus strapping and (3) strapping alone; active LLLT and strapping produced superior results after both five and ten treatments.

No reports were identified which examined the effects of laser on muscle lesions, though a few researchers have evaluated its use for painful points in muscle tissue (Waylonis, 1988; Ceccherelli et al, 1989; Snyder-Mackler et al, 1989). Results were mixed, with as many trials supporting the use of laser as reported it ineffective (Beckermann et al, 1992).

Discussion

The results of the clinical trials presented here represent a wide variety of methodologies and the use of many different treatment protocols, factors which make interpretation complex.

One of the greatest problems in interpreting the results of these trials is the great variety of dosimetry. Information from experimental studies has, in some cases, demonstrated a link between the dosages used and results achieved and this may have considerable significance for clinical practice. For example, it has been shown through the use of cell and animal studies that laser of different laser wavelengths may produce different results; it can be ineffective, stimulative or inhibitory depending on the dose used and the number, frequency and length of treatments appear to relate to outcome (Young et al, 1991; Zheng et al, 1992; Lubart et al, 1993).

Numbers of patients in the studies described vary from ones and twos (Oakley, 1982; Gorkiewicz, 1984; Gogia et al, 1988) to more than a hundred (Barclay et al, 1983; Williamson et al, 1986; McLachlan et al, 1991; Jun-Ying, 1992). Many recent papers report using randomised controlled trials (for example, Roche and West, 1984; Binder et al, 1985; McDiarmid et al, 1985; Callam et al, 1987; Lundeberg et al, 1987; Lundeberg et al, 1988 and McLachlan et al, 1991), though others, normally using few subjects, are descriptive (for example, Ferguson 1981; Oakley 1982; Gorkiewicz 1984; Gogia et al, 1988). Larger numbers facilitate randomization into groups and increase the reliability of results. Though both types of study can provide valuable information when undertaken and reported rigorously, it is not possible to extrapolate to larger populations from descriptive studies. Such studies may, however, provide useful pointers which can be followed up by more closely controlled trials, as in the evaluation of the efficacy of ultrasound in the treatment of breast engorgement (Shellshear, 1981;

Semmler, 1982; McLachlan et al, 1991). Ultimately, however, large randomised controlled trials are needed to examine the efficacy of all three agents.

The majority of recent papers describe their methods and assessments clearly but not all provide full details of the dosage parameters employed, a point highlighted by Calderhead (1991) with respect to laser. A simple statement of power or energy density in laser therapy, such as given by Mester and Mester (1989), is not adequate, given the effects variation in detail of parameters can cause. Studies of ultrasound suffer from similar problems; Williamson et al (1986) omit all details of dosage used in the trial and Oakley (1982) varied the dose as seemed clinically appropriate but omitted to provide details of the treatments selected. Other investigators such as Soren (1965) varied the dosage in W/cm^2 "according to pathology and the organ to be treated" and Gorkiewicz (1984) omits to note the frequency of ultrasound used. Similarly, reports of dosage for PSWD have lacked specificity, a common problem being those who report parameters in terms of the machine used; Pasila et al (1978), for example, describes dosage in terms of Diapulse and Curapuls machines and Barker et al (1985) states that the Therafield Beta was used at a high intensity setting. Lack of detail, especially of dosage, means that it is impossible to compare one trial with another, replicate or confirm the findings presented in a study and, of crucial importance in clinical practice, implement the findings in clinical practice.

The number of fully documented clinical trials of a reasonable size is still very small, especially when they are seen in the context of different pathological conditions and the contradictory nature of the findings to date. It is thus impossible to draw firm conclusions about the clinical efficacy of ultrasound, shortwave diathermy or laser in the treatment of soft tissue lesions or to identify those dosage parameters which may be most effective.

Little work has been done to evaluate the efficacy of shortwave diathermy but it is clear from this review that it is in question; it is interesting to note that many of the more recent studies, which are better reported and may have been conducted more rigorously, tend not to confirm the efficacy of this agent. Beckermann et al (1992), in a meta-analysis of studies relating to the use of laser, concluded that the evidence suggests that laser therapy appeared to be better than placebo for musculoskeletal conditions, though the same could not be said for the use of LLLT for skin lesions. Equally, though a greater amount of work has been conducted into the effects of ultrasound, the evidence for its clinical efficacy is presently inconclusive. Holmes and Rudland (1991) conducted a critical review of 18 studies purporting to examine the efficacy of US in the treatment of soft tissue lesions. They concluded that almost all studies were
as noted on the previous page,
methodologically flawed, and that 'the case for ultrasonic treatment of soft tissue injuries is not well founded at present'.

SECTION II

USAGE OF ULTRASOUND, SHORTWAVE DIATHERMY AND LASER IN PHYSIOTHERAPY PRACTICE

SECTION II: PREFACE

Section I has provided information about the nature, physical and physiological effects and clinical efficacy of ultrasound, shortwave diathermy and laser, information which is currently available to both researchers and, to a lesser degree, clinicians. Such information needs to inform practice and guide the use of each agent when treating soft tissue lesions. There is, however, considerable circumstantial and verbal evidence from practising clinicians to suggest that use and selection are made with little reference to what is known about the behaviour and efficacy of these agents.

Section II of the thesis will therefore examine the reported use of ultrasound, shortwave diathrmy and laser by a random sample of physiotherapists currently using electrophysical agents in the management of soft tissue lesions on a regular basis. Factors affecting selection will also be examined.

The section is divided into six chapters; the first two chapters review what is currently known about the clinical use of these agents on both a national and international level and identify and evaluate the investigative methods available to examine clinical practice. Chapter 3 and 4 report the results of the pilot studies conducted to develop the tool for the main study; this is reported in chapter 5. Finally chapter 6 discusses the issues raised by the results presented.

Section II. Chapter 1.

THE CLINICAL USE OF ULTRASOUND, SHORTWAVE DIATHERMY AND LASER

Electrophysical agents have been used extensively in the management of soft tissue lesions for the last fifty years or more and continue to be used for many purposes including the control and relief of pain and the enhancement of wound healing (Snyder-Mackler and Robinson, 1989; Lehmann, 1990; Low and Reed, 1990). A wide variety of modalities is available to the clinician who selects the treatment that is most suitable to the subject and lesion in question. Given the limited information available about the effects and efficacy of each, this is a complex task which may be influenced by a wide variety of factors.

Both general and local factors affect the selection and use of electrotherapy in clinical practice. General factors may include the geographical location of the practice and changes in 'fashion'. There is currently some evidence to suggest usage of agents may differ between countries (Michlovitz, 1990; Lehmann, 1990; Low and Reed, 1990). There is a tendency, for example, for practitioners in North America to use ultrasound to provide heating of tissues (Stoller et al, 1983; Black et al, 1984; Ziskin et al, 1990) and to regard laser with considerable suspicion (Lehmann, 1990). The latter has yet to be approved for use in clinical practice by the USA Federal Drug Administration Board. Conversely, ultrasound is rarely used for thermal treatments in Britain (ter Haar et al, 1987) and laser is gaining in popularity (Ide and Partridge, 1986, 1989; Baxter et al, 1991); the literature suggests that similar patterns to those emerging in Britain may prevail in Australia (Lindsey et al, 1990; McMeekan and Stillman, 1993), though McMeekan (1994) has suggested that practitioners are split in their views, some following the British and some the American line of thought.

Fashion can be a factor; Wadsworth and Canmugan (1988) suggest that the past few years have seen considerable change in the therapists' views of electrotherapy and their subsequent use of it and warn that changes, though possibly desirable, should be based on scientific evidence, of the type described in section I of this thesis, rather than fashion. As new pieces of equipment becomes available on the market physiotherapists may be persuaded, particularly by manufacturers, to adopt them despite a lack of knowledge about their effects and efficacy and a limited understanding of their usage (McMeekan and Stillman, 1993). Such problems appear to have arisen in clinical practice with the use of laser equipment and a number of the newer forms of muscle and nerve stimulating currents such as interferential, 'h' waves and rebox. Both laser and interferential stimulation were shown by Ide and Partridge (1986; 1989) to be purchased increasingly frequently whilst at the same time therapists in Northern Ireland were complaining of poor information and a lack of understanding of laser (Baxter et al, 1991), and few studies were available to confirm the effects of either agent (Kitchen and Partridge, 1991; Goats, 1991).

Local factors also affect usage; these may include the availability of equipment, the financial constraints placed upon therapy managers, the experience and training of individual practitioners, the types of practice in which the therapists function and the marketing practices of manufacturers.

Knowledge about the clinical use of electrophysical agents and the factors governing selection of both agent and dosage is scant, with few studies having examined these areas in Britain or elsewhere. Some researchers have examined the use of single agents such as laser (Baxter et al, 1991; McMeekan and Stillman, 1993) or ultrasound (ter Haar et al, 1987; DWH, 1980b) whilst others have compared agents (Lindsey et al, 1990; Robinson and Snyder-Mackler, 1988; DWH, 1980a,b).

Four studies have been identified which examine the clinical use of electrophysical agents in Britain. Ide and Partridge (1986) initiated the process by describing the stocks of equipment held by both National Health Service departments and private practitioners, the age of that equipment and whether it was in regular usage. They described servicing practices and replacement and funding policies. A further study by the same authors, reported in 1989, examined the replacements which had been bought in the previous two years within the NHS. Over 25,000 pieces of equipment were found to be held within the NHS whilst the smaller sample of private practices reported owning over 1000 pieces of equipment. By 1989, more than 1000 pieces of equipment had been discarded and almost 3000 new pieces acquired in the National Health Service. Those most frequently purchased were transcutaneous nerve stimulators, shortwave diathermy, ultrasound and interferential equipment; the number of laser generators, though small in 1986 (n=42), was reported to be rising rapidly, a 250% increase being reported by 1989.

The first of these studies (Ide and Partridge, 1986) was followed in 1987 by that of ter Haar et al (1987) who examined the use of therapeutic ultrasound in both private and state care. Of those returning the questionnaire (n=2420), 84% of therapists in the National Health Service (NHS) reported having used ultrasound at some time and 100% of private practitioners reported currently making use of the agent. Twenty percent of treatments given by NHS staff and 54% of treatments recorded by private practitioners involved the use of ultrasound. ter Haar et al (1987) reported on the types of machines used, the frequencies and intensities most commonly employed and types of conditions treated. Ultrasound was found to be combined with a wide range of therapy techniques. Both private practitioners and NHS staff reported receiving undergraduate tuition (35% and 68% respectively) and attending postgraduate courses (47% and 83% respectively) in the use of ultrasound.

By 1991, laser treatment was becoming more common in the treatment of patients; this was indicated by the work of Ide and Partridge (1989), reports from manufacturers and verbal reports from clinical practice. Baxter et al (1991) examined a number of aspects of its use in Northern

Ireland. The objective of the study was reported to be to assess the current usage of laser in the Province and also collect information about the views of therapists concerning the efficacy of low level laser therapy in clinical practice. This evaluation focused on the perceptions of practising clinicians of patient attitudes to laser and their own perceptions of the clinical efficacy of the agent. Types of conditions treated, beliefs about hazards and sources of information about laser were also noted. The perceived efficacy of laser for pain relief, reduction of oedema and the stimulation of wound healing was compared with that of interferential, pulsed electromagnetic energy, shortwave diathermy and ultrasound. The results of this study suggest that laser was regarded by this group of respondents as the most effective treatment for pain relief and wound healing. The respondents reported treating a wide variety of conditions with laser; these included soft tissue lesions, the arthropathies and the symptom of pain. This list compares closely with that elicited by ter Haar et al (1987) for the use of ultrasound.

No respondent reported having received formal tuition on the use of laser at the undergraduate level and only 42% had attended formal post graduate courses. The remainder had received instruction through manufacturers literature and demonstrations, local departmental tuition, the use of the literature and personal experience. Most respondents (94%) were dissatisfied with the information they had received.

A number of studies have reflected practice in North America and Australia. One of the earliest studies examining the use of electrotherapy was conducted by Venton-Gough (1962); he examined the use made of electrophysical agents by 10 institutions in Montreal during 1961, by examining patient records. Shortwave diathermy (in this case, the continuous form) was the most frequently used agent (30% of all treatments) whilst ultrasound constituted 12%; laser did not feature. Both SWD and US were deemed thermal agents by the author, who noted that 88% of all treatments made use of some form of heating. The Canadian Department of Welfare and Health (DWH) followed this study with an appraisal of the usage of ultrasound, shortwave and microwave diathermy devices in use during 1977 (DWH, 1980a; 1980b). A total of 4254 questionnaires were sent out to hospitals, chiropractic, sports medicine and physiotherapy clinics and a 61% response rate achieved. No details are given of the response rates for individual groups. On a number of occasions throughout the report the authors used this data to extrapolate results for the whole group; such results are suspect, however, as no information is available to show that the respondents and non-respondents had similar characteristics. Of the 2,567 respondents, 927 (40%) reported using US and 618 (24%) using SWD. An estimated total of 3,920,987 US treatments and 1,380,188 SWD treatments were delivered during 1977, the vast majority of which employed a continuous mode for both agents. A wide variety of machine types were reported but calibration of these devices was low, with only 47% of US and 43% of SWD devices receiving attention. Respondents were asked about their experience of adverse effects with usage of this equipment; 8%

reported problems such as pain and burns with US and a further 8% noted effects such as pain, burns and pace maker interference with both shortwave diathermy and microwave diathermy. Not all operators reported being trained in the use of their equipment; 72% claimed to be trained in the use of US and 54% in the use of SWD.

The only other report identified from North America compared the availability and frequency of use of ultrasound with electrical stimulating currents (Robinson and Snyder-Mackler, 1988). Little information is given about the ultrasound as these authors were primarily examining the use of the stimulating currents. They note, however, that ultrasound was used more frequently than any other form of treatment examined; 45% of respondents reported using it 10 times a week or more, a level almost three times greater than any other agent. General questions were asked about the sources of information; respondents reported their primary source of postgraduate knowledge to be colleagues (43%), publications (25%), the manufacturers (25%), postgraduate seminars (20%) and graduate education courses (1%).

Three studies have addressed the use of electrotherapy in Australia; Dennis (1987) studied the manner in which physiotherapists in the private sector responded to referrals made to them. As part of this work he reported that 51.9% of 477 referrals by other health care professionals were for electrotherapy treatments; of these, 94 were for ultrasound and 79 for shortwave diathermy. Lindsey et al, (1990) expanded this work, examining the ownership and frequency of usage of electrotherapy equipment in private physiotherapy practices in Brisbane. Frequency of usage, case load, the special interests of the respondents, their age and training institution were examined. Ultrasound, transcutaneous nerve stimulation and interferential were found to be the most frequently used modalities; this is in accordance with the work of Ide and Partridge (1986; 1989) in Britain, which suggested that these agents were held in greatest numbers. Shortwave diathermy units were reported to be present in most departments in the Australian study but did not rank amongst those most frequently used.

In 1993, McMeekan and Stillman reported a study of the use of laser by practitioners in Victoria, Australia; subjects were identified on the basis of known purchases. Indications for treatment, techniques, dosages, expectations and outcomes were evaluated and information collected about background knowledge and laser possessed through the use of a questionnaire. Respondents reported treating the elbow and shoulder regions most often; the disorders most commonly treated were soft tissue (with tendinitis and ligamentous lesions most common), circulatory, pain and the arthropathies. Pain relief and wound healing were the most frequently expected effects. Over half of the respondents attended seminars prior to purchasing a laser, though the literature (journals and other) was generally considered the most valuable source of knowledge.

These studies suggest wide usage of electrophysical agents in the treatment of soft tissue lesions using a variety of modalities, despite limited knowledge about the efficacy of many. The quality and nature of these studies, however, vary greatly in terms of the sampling techniques used, sample size, response rates and the questions asked.

Sample characteristics vary according to the methods used to select the subjects. Some researchers examined usage within a local area; Robinson and Snyder-Mackler (1988) approached physical therapy clinics associated with the physical therapy programmes of two academic institutions; Lindsey et al (1990) contacted all private practitioners within the Brisbane (Australia) city limits and McMeekan and Stillman (1993) mailed therapists in Victoria, Australia. Lindsey et al (1990) note one of the main problems with this approach when they stated that over 77% of clinicians they contacted were trained at a single institution, a result which might influence the trends shown. In contrast, the Canadian Department of Welfare and Health (1980a; b), Ide and Partridge (1986; 1989) and ter Haar et al (1987) all employed national samples. Their results are, therefore, more likely to be representative of the approaches and practices of those in Canada and Britain respectively.

Sample size also varied, ranging from 10 (Venton-Gough, 1962) to 4254 (Canada Department of Health and Welfare), with the majority of researchers employing between 100 and 250 subjects. No studies reported randomisation in their selection procedures. Small numbers, lack of randomisation or local distribution can lead to spurious results; in addition small numbers are unlikely to be representative of larger populations and it is therefore not possible to generalise such results to such groups.

A number of studies demonstrate low response rates to the questionnaires sent out, which again can lead to distortion of results; Baxter et al (1991) sent out 215 questionnaires to therapists with experience of the use of laser and 63% were returned. Unfortunately, a number of these papers were discarded as the researchers believed the respondent to have an inadequate level of experience in the use of laser therapy; this practice may have introduced bias into the study. Robinson and Snyder-Mackler (1988) distributed 490 questionnaires to physical therapy clinics and achieved a 45% return rate. McMeekan and Stillman (1993) contacted 122 practitioners and asked them to complete questionnaires about the use of laser; 38 replies were received, giving a 31% response rate. Such low response rates are likely to distort the results obtained, making conclusions suspect, as those responding may not represent the views of the general population of therapists. In contrast, Ide and Partridge (1986; 1989) achieved an overall response rate of 86% in their first study and 90% in the second whilst Lindsey et al (1990) received back 70% of their questionnaires. ter Haar et al (1987) reported receiving information from 204 National Health Service departments and 191 private practitioners; however, no information was given about the number of departments or private practitioners initially contacted, making it impossible to determine the percentage return rate.

A number of questions were addressed in the studies; these included the types of equipment available to clinicians (Ide and Partridge, 1986, 1989; ter Haar et al, 1987; Robinson and Snider-Mackler, 1988; Baxter et al, 1991; McMeekan and Stillman, 1993), the frequency of usage of individual agents (ter Haar et al, 1987; Lindsey et al, 1990; Robinson and Snider-Mackler, 1990), the types of conditions treated with named agents (ter Haar et al, 1987; Baxter et al, 1991; McMeekan and Stillman, 1993), the types of equipment used (ter Haar et al, 1987; Baxter et al, 1991; McMeekan and Stillman, 1993), sources of information informing practice (ter Haar et al, 1987; Robinson and Snider-Mackler, 1988; Baxter et al, 1991; McMeekan and Stillman, 1993), treatment parameters used (ter Haar et al, 1987; McMeekan and Stillman, 1993) and safety precautions employed (ter Haar et al, 1987; Baxter et al, 1991). The perceived efficacy of agents was examined by Baxter et al (1991) and McMeekan and Stillman (1993). Ide and Partridge (1986) inquired about the perceived importance of electrotherapy. They reported that 59% of respondents agreed that electrotherapy was 'an important priority area in physiotherapy'. Many respondents suggested that electrotherapy was of greater importance in outpatient treatments but was clearly an adjunct therapy.

The majority of these studies, originating from three continents, have been conducted over the last 15 years and cover ultrasound, shortwave diathermy and laser, with least attention having been paid to the use of shortwave diathermy in either its continuous or pulsed forms. Many have suffered from local distribution, lack of randomisation and poor response rates. Few direct comparisons have been made between the use of these three agents, which may achieve similar therapeutic effects and little has been done to examine the factors affecting therapists' selection of treatments for individual patients and conditions and their beliefs about the effects and efficacy of these agents.

There has recently been a proliferation of new types of equipment but limited evidence of their biological effects, clinical efficacy and safety (Kitchen and Partridge, 1990; 1991). Lindsey et al (1990) suggests that such lack of basic information will inevitably lead to other factors influencing selection and use of agents. These might include the availability of equipment, the level of experience of the therapist, the beliefs of practitioners about the effects of individual agents, marketing strategies used by manufacturing companies, current and prior training in the use of electrophysical agents and the types of practice in which the therapists' function~~s~~ (Lindsey et al, 1990; McMeekan and Stillman, 1993).

It is therefore essential that nation wide surveys are conducted which examine the usage of a number of agents in clinical practice in order to provide information which reflects more accurately the clinical practices and choices of therapists currently using electrophysical agents on a daily basis.

Purpose of the current study

Ultrasound, shortwave diathermy and laser are present in many clinical departments throughout Britain and anecdotal evidence suggests that they are frequently used to treat soft tissue lesions. Basic biological studies and clinical trials, reviewed in Section I of this thesis, suggest that these agents may effect a variety of changes, some of which may be similar. Little is known, however, about the relative use therapists make of each modality; the types of lesions treated, the frequency with which each agent is used and ways in which modalities are combined are unexplored. In addition, factors affecting selection, beliefs about usage, effects and efficacy and the sources of information most commonly used by therapists remain unknown.

The purpose of Section II of this thesis is therefore to evaluate and compare the current usage of ultrasound, shortwave diathermy and laser in clinical practice in England. These agents are examined in relation to the management of the healing of soft tissue lesions. The objectives of this phase of the research were:

1. To determine the proportion of practitioners with access to each agent
2. To examine the frequency of usage of each agent
3. To identify the disorders being treated with each agent
4. To identify and examine factors influencing choice of agent

5. To examine attitudes and beliefs of practitioners which affect treatment selection

6. To identify and evaluate the sources of information utilised by practitioners

The following chapter will examine the research methods available to fulfil these objectives and identify that which is most suited to the task.

Section II. Chapter 2

USAGE OF ELECTROPHYSICAL AGENTS: RESEARCH METHODOLOGIES

In this chapter, methods of data collection available to monitor the selection and usage of ultrasound (US), shortwave diathermy (SWD) and laser are examined first. Their strengths and weaknesses are assessed and their appropriateness for the purposes of this study are critically considered. Secondly those selected are identified, and reasons are given for the choices made.

Four types of data collection are reviewed. These fall into two categories, retrospective and prospective, and include (1) the use of historical data, (2) observational techniques, (3) the collection of concurrent information by practitioners and (4) surveys. The majority of work to date examining the use of electrophysical agents have made employed survey methods, examples including the work of the Canadian Department of Welfare and Health and Welfare (1980 a,b), Baxter et al (1991) and McMeekan and Stillman (1993). A number of methods were however, examined to ensure selection of the most appropriate method for the present study.

Retrospective methods

In medical practice, patient case notes and treatment records may be used to collect information about past practice. In order for the data derived to be reliable and valid the data base used must conform to strict standards; accurate and comprehensive records must be available and the data be present in a coherent and standardised form. When this is not so, considerable loss of information can result (Seaman, 1987; Moser and Kalton, 1991).

The main strength of retrospective information is that it reflects daily clinical practice which has not been affected by the imposition of research processes which may themselves result in altered practice (Moser and Kalton, 1991; Polit and Hungler, 1991). As the method does not rely on the long term memory such data is not distorted through poor recall or the imposition of personal perceptions by the respondent. In addition, the method has the advantage of speed (Moser and Kalton, 1991) and is relatively inexpensive (Seaman, 1987).

Retrospective studies are, however, subject to weaknesses, particularly if the data collected was originally intended for administrative purposes (Pocock, 1983; Moser and Kalton, 1991). The key issues which must be addressed are (1) the accuracy of the data, (2) the format of the data and (3) missing data (Pocock, 1983; Seaman, 1987; Moser and Kalton, 1991; Polit and Hungler, 1991). Records may be incomplete or their format varied, resulting in discrepancies. Changes in practice or circumstances may arise which are not recorded; for example, equipment availability may change or local referral systems and funding policies may alter. Despite the collection of copious amounts of material it is rarely possible to collect adequate data from a wide sample of subjects (Moser and Kalton, 1991). In addition, this type of study is unable to provide information about reasons for treatment selection or the beliefs that underpin such choices. Finally Burns and Grove (1993) suggest that issues of confidentiality may arise when medical records are accessed, particularly following the advent of the Privacy Act of 1974.

This method was used to gain an insight into the usage of electrophysical agents in clinical practice by Venton-Gough (1962), who examined patient case notes for the year 1961. His study exemplifies many of the problems associated with retrospective studies in that the number of units accessed was small (n=10) and, though large volumes of data were derived, the information derived was limited. The conclusions from such studies must, for all these reasons, be treated with caution (Pocock, 1983; Seaman, 1987; Moser and Kalton, 1991).

Observational methods

Whilst observation forms a fundamental part of all research processes, it is used as a specific research technique in the social sciences (Kazdin, 1982; Moser and Kalton, 1991; Carr, 1991). Both non-participant and participant techniques may be used; the researcher may observe and record the actions and behaviour of subjects from a neutral position outside the situation or may participate in the action and observe from within (Moser and Kalton, 1991).

Observational studies have a number of strengths and are of particular value when informants are unable or unwilling to provide information, to verify procedures and practices and to avoid problems over accurate recall (Moser and Kalton, 1991; Carr, 1991). They have, however, a number of major weakness; these studies are time consuming and it is difficult to obtain a representative sample, as numbers are often low (Carr, 1991). Both types of observation may lead to modifications in the behaviour of the subject due to the presence of the researcher.

Many researchers believe that observational studies are better suited to situations where other methods such as interviews, questionnaires or direct measurement are not possible, such as when dealing with children or mentally handicapped subjects, or when addressing sensitive issues such as deviant behaviour (Kazdin, 1982; Moser and Kalton, 1991; Carr, 1991). In addition, Carr (1991) suggests that they can be useful at the preliminary stage of more extensive investigations to generate ideas and hypotheses.

Though this technique has been used in a number of health care situations such as the study of the social engagement levels of people with physical disability (Newton et al, 1989) and patient compliance with instructions (Fjellstedt and Sulzer-Azarroff, 1973), its use has not been documented with respect to the use of electrophysical agents.

Concurrent records of practice

A second method of prospective data collection involves the clinician in recording instances of a named behaviour. When using this method, it is necessary to define precisely the information to be collected and identify clearly the subjects who will collect the information; the investigators must also ensure that the subjects taking part in the study understand the need for high levels of compliance in order to avoid loss of information (Kazdin, 1982; Moser and Kalton, 1991).

The main strengths of this method lie in its ability to access practice directly, to collect information which is current and to avoid the problems often associated with recall of material (Pocock, 1983; Hulley and Cummings, 1988; Polit and Hungler, 1991). The method, however, again suffers from a number of weakness; firstly, subject compliance is often low, leading to loss of data and possible distortion of results (Ley, 1987). Secondly, this method can be time consuming if the incident being monitored occurs frequently, exacerbating problems of compliance. As copious amounts of data are sometimes generated it is often only possible to employ the technique over short periods of time and with a limited number of subjects (Kazdin, 1982). Consequently it can be difficult to achieve an adequate sample of data which is representative of the general population using the agent in question (Moser and Kalton, 1991).

This method appears to have been used by ter Haar et al (1987) and Dennis (1987) to examine use of electrophysical agents; they reported, respectively, the numbers of treatments given and referrals received by therapists over a period of one week. ter Haar et al (1987) obtained and analysed a vast quantity of data from a large national sample whilst Dennis (1987) examined a much smaller sample. Both sets of results may have been affected by the short duration of the studies and lack of compliance, though there is no evidence available of this.

<u>Survey methods</u>

Survey methods cover a wide range of techniques and include the use of face-to-face interviews, conducted and recorded by a researcher, and forms, or questionnaires, which are normally completed by the subject.

Interviews can be used to elicit factual information or details about the beliefs and opinions of the subject and may fall into one of two major categories: (1) the exploratory or (2) the standardised interview. The first normally consists of in-depth, unstructured or partially structured discussions which are essentially heuristic in nature (Banaka, 1971; Ericsson and Simon, 1980; Oppenheim, 1992) whilst the second is more structured, the format frequently resembling that of a questionnaire. In both cases, specific information is collected about preselected topics, data being derived in response to questions, instructions or more general probes (Ericsson and Simon, 1980). In contrast questionnaires are generally highly structured, ensuring that all subjects are presented with the same requests for information and offering less opportunity for the pursuit of individual interests.

There are a number of advantages in using survey methods to collect data. Questionnaires may be used to obtain information from large population samples spread across wide geographical areas (Seaman, 1987; Polit and Hungler, 1991); they facilitate the collection of large quantities of data within a short period of time and may allow data to be collected on more than one occasion (Oppenheim, 1992).

The format of surveys vary and, through the use of open and closed questions, markedly different types of information can be elicited. Open questions facilitate the generation of rich, in-depth data which may be used to develop new ideas and hypotheses whilst closed questions are used to gather specific information on areas determined by the researcher and may involve the use of check lists, attitude scales, projective techniques, rating scales and factual questions (Beed and Stimpson, 1985; Streiner and Norman, 1989; Fowler and Mangione, 1990; Oppenheim, 1992).

Whilst interviews facilitate discussion and generate in-depth data, postal questionnaires can be regarded as less threatening than face-to-face meetings, ensure anonymity of the subject and are less time consuming for both respondent and researcher (Seaman, 1987; Converse and Presser, 1988).

A number of disadvantages are associated with the use of surveys of different types. The use of face to face schedules normally limits access to subjects; time, distances and costs may affect the sample size and geographical spread of subjects and consequently restrict the general application of the information derived (Fowler and Mangione, 1990). Face to face contact between subject and researcher can introduce bias into a study as the subject may react in socially desirable ways. They may be flattered by the attentions of the interviewer, may choose to attempt to control the interviewer, provide spurious answers or those they believe to be acceptable. Bias may also be introduced directly by the interviewer; rapport must be maintained with the respondent in order to facilitate conversation without unduly influencing the material elicited.

Self report techniques required by this type of design can lead to additional problems; the subjects may fear the use to which results may be put or fear appearing stupid, ignorant or antisocial (Seaman, 1987). Long term memory problems can lead to difficulties with recalling information over long periods and can therefore reduce the reliability of information elicited by schedule unless care is taken to match the recall period to the area addressed (Oppenheim, 1992; Ericsson and Simon, 1980). Finally, poor question or probe design and participant discussion and collusion may also give rise to bias within the study (Belson, 1981; Streiner and Norman, 1989; Oppenheim, 1992).

Work based on the use of interviews has been reported in many areas of research including the evaluation of patient's attitudes to the management of hypertension (Morgan and Watkins, 1988) and perceptions of factors determining both high and low quality nursing care (Norman et al, 1992); however, there are currently no such studies reported in the literature about the use of electrophysical agents in clinical practice, though some workers note that they have used a limited number of informal interviews to guide their main study. Ide and Partridge (1986) interviewed three superintendent physiotherapists in the pilot stage of developing their questionnaire and McMeekan and Stillman (1993) indicate that they had 'preliminary discussions' with clinicians prior to the structuring of their tool. As in these cases, interviews may precede other types of investigation, providing in-depth information about a topic and forming a basis for further work.

Questionnaires have been used by the majority of researchers to collect information about the use of electrophysical agents in clinical practice (for example, Ide and Partridge, 1986, 1989; ter Haar et al, 1987; Lindsey et al, 1990; Baxter et al, 1991 and McMeekan and Stillman, 1993). This method has allowed them to contact large groups of subjects across wide geographical areas (DWH, 1980 a,b; ter Haar et al, 1987); to ensure that all subjects have been asked the same questions in the same way and thus to be able to compare the answers, and to access both factual (Ide and Partridge,, 1986, 1989; Robinson and Snyder-Mackler, 1987; Lindsey et al,

1990) and attitudinal information (Baxter et al, 1991; McMeekan and Stillman, 1993).

Discussion

All of these designs and techniques have both advantages and disadvantages. Many of the problems identified can be minimised through the use of careful piloting of the procedures used, standardization of processes, rigorous training of the researchers and systematic checks on the procedures employed during the course of the study (Hyman et al, 1954; Kahn and Cannel, 1961; Sudman and Bradburn, 1974; Pocock, 1983; Moser and Kalton, 1991; Oppenheim, 1992). Reliability may be further increased by providing information which guarantees anonymity and confidentiality to subjects involved in studies (Sudman and Bradburn, 1974; Converse and Presser, 1988; Fowler and Mangione, 1990).

This study required a means of accessing factual information about the use of ultrasound, shortwave diathermy and laser in the management of soft tissue lesions and information about the attitudes and beliefs of the physiotherapists involved. Following a review of previous work in the area, consideration of the needs of this study and an examination of the methods available, survey methods were selected as the most appropriate.

Both the use of interview schedules and questionnaire was thought necessary in this study. Open ended interview techniques were selected for both the prepilot and pilot phases to facilitate in-depth discussion about a wide variety of aspects of the selection and usage of electrophysical agents in clinical practice and allow subjects to introduce elements not previously considered by the researcher. This provided a valid clinical basis for the development of the questionnaire which would subsequently be distributed to a randomly selected sample of therapists throughout England. This work was important to minimise the difficulties experienced by others in achieving satisfactory response rates, a problem which may have arisen because the questionnaires failed to address issues which were perceived as pertinent to daily practice by the respondents (Robinson and Snider-Mackler, 1987; Baxter et al, 1991; McMeekan and Stillman, 1993). Both open interviews and semi-structured interviews were selected in order to develop ideas and hypotheses about the current use of US, SWD and laser and the factors affecting usage of the different agents.

Questionnaires were selected as the investigative method for the main study as they allowed wide geographical coverage and large numbers of subjects to be accessed. The method facilitated uniformity of questioning and was a quick, cost effective and non-threatening technique. Care was taken to minimise the disadvantages of the survey technique previously noted and thus to increase its reliability and validity. These aspects are addressed in further detail in the following chapters which deal with each phase of the study.

PHASE I. PRE-PILOT STUDY TO EXAMINE THE CLINICAL USE OF ULTRASOUND, SHORTWAVE DIATHERMY AND LASER IN ENGLAND

The purpose of the pre-pilot phase was to obtain preliminary information which would facilitate an exploration of the level of usage of electrophysical agents in clinical practice, the purposes for which ultrasound (US), shortwave diathermy (SWD) and laser were used and the factors which governed their selection. Information collected during this phase was used to inform the following two phases.

Prior to the conduct of the pre-pilot study, development work was undertaken in order to ensure that the study addressed the issues which were of relevance to the current clinical usage of electrophysical agents in Britain.

I. THE DEVELOPMENT OF THE PRE-PILOT STUDY:

Owing to the lack of information about the current usage of electrophysical agents in Britain, preliminary, open interviews with experienced therapists currently using electrophysical agents in the management of soft tissue lesions were undertaken to explore current practice and elicit and develop ideas and concepts upon which further study would be based.

Prior to the conduct of the interviews, a number of categories were identified which were used to initiate and guide the discussion. They were developed on the basis of an examination of the literature, discussed in chapter 1 of this Section, and addressed the following issues:

- the availability of equipment,
- the level of usage of electrophysical agents in clinical practice
- the purposes for which US, SWD and laser therapies were used
- the factors which governed their selection.

As the volume of literature addressing the use of electrophysical agents in clinical practice is limited, and a number of the studies have been conducted in countries other than Britain, these categories provided guidelines only for the conduct of each session. There was no clear indication from the literature, however, that they would cover all the issues of current concern to physiotherapists practising in this country at the present time. It was, therefore, of great importance that interviewees should be encouraged to introduce and discuss issues which were of particular concern to them in their current clinical practice.

The data derived from these interviews was scrutinized; themes or categories were identified in the material and examined in relation to the literature. Full details of the procedure are provided in the following section.

II. CONDUCT OF PRE-PILOT STUDY:

Pre-pilot work was conducted to initiate the development of ideas and hypothesis about the use of electrophysical agent in current clinical practice in the management of soft tissue lesions.

Design: Unstructured interviews.

Subjects: A convenience sample of four physiotherapists was interviewed; subjects were selected as representative of the group defined in the inclusion criteria and were either known to the researcher or identified by others as experienced in the area.

Inclusion criteria:

* subjects should be practising physiotherapists
* subjects should be currently using electrophysical agents in the treatment of soft tissue lesions
* subjects should represent different clinical backgrounds
* subjects should have a minimum of two years experience in the use of electrophysical agent in the management of soft tissue lesions

Procedure: Written information was provided for each subject about the objectives of the interviews; written permission to conduct the interviews was sought and confidentiality and anonymity assured (Appendix 1).

All interviews were conducted at the subject's place of work and lasted for an average of forty minutes. Each interview was introduced using a standard introduction (Appendix 2).

The following four core areas were used as probes in each interview:

: the availability of equipment

: the level of usage of each type of equipment

: the types of lesions and conditions treated with US, SWD and laser

: factors affecting choice of agents

During each interview the subject was encouraged to introduce and discuss or describe their own current clinical practice. In three interviews all four core areas of discussion were initiated by the subject; the researcher initiated discussion about the level of usage of agents in the last instance.

Notes were made during the course of each interview. Full notes were written up following each interview and returned to the subjects for scrutiny and confirmation (Appendix 3). A number of additions and clarifications were made at this stage in the light of comments made by the subjects.

Analysis: Each set of notes was scrutinised by the researcher and themes were identified from the material. Both amended copies of the notes and the themes were sent back to the subjects and the subjects asked to check whether the themes reflected the material in the notes and their views. A list of themes was then constructed which reflected the views of the group.

<u>**Results**</u>: Four physiotherapists provided information about their current use of electrophysical agents to treat soft tissue lesions.

1. Subjects: Two subjects practised within the National Health Service, one was a self employed private practitioner and one employed in industry. Time since qualification varied from 3.5 to 12 years (mean: 4.5 years) and experience in the use of electrophysical agents in the management of soft tissue injuries varied from 2 to 8 years (mean: 4.5 years).

2. Access to agents: Of the agents under consideration, two subjects had access to ultrasound, shortwave diathermy and laser, and two subjects had access to ultrasound and shortwave diathermy alone. All subjects had access to other electrophysical agents including microwave diathermy (n=1), ultraviolet equipment (n=2), infrared equipment (n=4), transcutaneous electrical nerve stimulating equipment (n=4), interferential (n=4) and other muscle and nerve stimulating equipment (n=4).

3. Themes: The following themes were identified from the four sets of notes:

: types of electrophysical agent available:

: factors governing availability of agents

: types of agent used in the management of soft tissue lesions

: selection of electrophysical agents for the management of soft tissue lesions

: dosages

: progression of treatments

: adjunct usage of electrophysical agents

All subjects contributed information about each of these categories. Three subjects stated that they used electrophysical agents despite reservations about their efficacy. Additionally two subjects contributed information about a number of the following areas; undergraduate and postgraduate training, the placebo effects of electrophysical agents and the physiological effects of one or more agents.

PHASE II. PILOT STUDY TO EXAMINE THE CLINICAL USE OF ULTRASOUND, SHORTWAVE DIATHERMY AND LASER IN ENGLAND

The purpose of the second phase of this research was to identify more closely the key concepts used by clinicians to determine use and selection of ultrasound (US), shortwave diathermy (SWD; pulsed P, continuous C) and laser in the management of soft tissue lesions. Prior to the conduct of this phase of the study, development work was undertaken in order to ensure that the issues addressed during this phase were both relevant and important to the clinicians being interviewed and to ensure that the methodology used was appropriate to the aims of the study and that the conclusions drawn from the study were reliable and valid.

I. THE DEVELOPMENT OF THE PILOT STUDY:

Following the pre-pilot work, semi-structured schedules were developed to check the validity of the previous phase, which employed only four subjects, and to explore in greater depth the use by physiotherapists of electrophysical agents in the management of soft tissue lesions.

Development of probe topics

Six probe areas were developed which would be used to guide the course of the interview; these probe topics were identified following an examination of the literature discussed in chapter 1 of this Section, and on the basis of the pre-pilot work (chapter 3). Examples of issues raised in the literature and examined at this stage included conditions treated (ter Haar et al, 1987; Baxter et al, 1991; McMeekan and Stillman, 1993), dosage selection (ter Haar et al, 1987; McMeekan and Stillman, 1993) and adjunct usage of electrophysical agents (ter Haar et al, 1987). All issues raised at this stage had been identified at the pre-pilot stage of the current investigation.

Data analysis

The verbal communications derived from the interviews were analysed through the use of content analysis (Krippendorff, 1980; Fowler and Mangione, 1989; Downe-Wamboldt, 1992).

Reliability and validity

The reliability of interview studies is dependent on selection of subjects, the conduct of the interviews and the analytical methods used (Converse and Presser, 1988; Oppenheim, 1992).

Following an examination of the possible sampling methods, it was decided that a judgement sample would be suitable for this phase. Inclusion criteria were developed to ensure a representative group of practising clinicians was selected. Subjects should be physiotherapists with varying levels of experience who were currently using electrophysical agents in the management of soft tissue lesions; they should represent different clinical backgrounds and be drawn from different geographical locations.

Partial standardisation of each interview was planned; a standardised introduction was developed for use prior to each interview to outline the objectives of the interview and to assure each subject of anonymity and confidentiality. Additional uniformity was achieved through the use of a standard format to introduce each probe; these would only be used when the issue did not arise spontaneously within the course of the conversation.

Finally, reliability was maximised through the development of a detailed procedure for the analysis of the data. This procedure is described in the following section.

The validity of the procedures used in this phase (phase II) of the study were established through attention to, firstly, the topics addressed and, secondly, the categories or themes derived during analysis. Face, content and construct validity of the probe topics identified was examined; both face validity and content validity were maximised by primarily developing the probes on the basis of information derived directly from experienced clinicians. These forms of validity were checked by submitting the list of probe areas to the four interviewees used in the pre-pilot study and two additional independent assessors for examination; these subjects confirmed that the probe areas listed reflected current clinical concerns fully and reasonably.

Construct validity was maximised by checking the probe topics developed against the literature already discussed in Section II, chapter 1.

The validity of the categories developed during analysis was investigated; content validity was established by the use of independent assessors with knowledge of the field to confirm the presence of the categories developed by the researcher and to identify the individual occurrences of statements referring to specified themes or categories. Concurrent validity was examined by comparing the results obtained from this phase of the study with those presented in the literature and with the data derived during phase I, reported in the previous chapter. Though a wide variety of opinions and practices is legitimate in this type of study, the aim of this part of the work was to investigate those which were common to the majority of subjects.

II. THE CONDUCT OF THE PILOT STUDY:

Semi-structured interviews were conducted with a judgement sample of physiotherapists to obtain information about the usage of ultrasound, shortwave diathermy and laser in the management of soft tissue lesions. The purpose of this phase of the study was to examine in depth key concepts used by clinicians to determine use and selection of these agents. The investigation centred around the types of lesions commonly treated, the factors influencing the use and selection of each modality and the adjunct role of these agents. This information was subsequently used in the following phase to inform the development of the questionnaire which was sent to a random selection of practising clinicians.

Design: Survey: semi-structured interviews.

Subjects: Ten subjects were selected from six health regions and four types of clinical practice (outpatient departments in the National Health Service, community care, private practice and industrial practice).

Inclusion criteria:

* subjects should be practising physiotherapists
* subjects should be currently using electrophysical agents in the treatment of soft tissue lesions on a regular basis
* subjects should represent different regional locations

* subjects should represent different clinical backgrounds

* subjects should represent different levels of experience of physiotherapy practice and use of electrophysical agents

Materials

1. Tape recording equipment

2. List of probe topics: six probe areas were addressed in each interview. These were developed on the basis of information gained from the literature and the pre-pilot interviews previously described. The probe areas developed for this study were as follows:

i. types of soft tissue problem treated with electrophysical agents.

ii. electrophysical agent used in the treatment of soft tissue lesions.

iii. selection of electrophysical agent.

iv. selection of dosage.

v. progression of treatment.

vi. the adjunct use of electrophysical treatments.

The term 'problem' instead of 'condition' was used in the first probe in order to avoid limiting the responses of the respondents. The pre-pilot work suggested both specific condition and signs and symptoms might feature as indications for electrophysical treatments.

Procedure: Prior to the conduct of each interview, subjects were provided with information about the purpose of the study and the procedure to be used (Appendix 4). Written agreement was sought to conduct each interview and permission was gained to sound tape the session.

Subjects were interviewed, either at their place of work or at the Kings College London. Each interview was preceded by a short standardized verbal introduction (see Appendix 5); subjects were told that the experimenter was interested in their current working practices and views about the use and selection of electrophysical agents in the management of soft tissue lesions. They were again assured of personal anonymity in all reports and it was stressed that the interviewer was interested in their personal views and practices and that there were no right and wrong answers to probes.

Subjects were first asked to describe the types of patients they most frequently encountered and the forms of electrophysical agents available to them. These areas were straightforward and factual and allowed the subjects to relax and begin talking about their practice as the pre-pilot work indicated that some subjects might regard certain aspects of the interview as sensitive if the interviewer was perceived to be judgemental in any way. Subsequently, each probe area was addressed, the order varying according to the issues raised by the individual clinician. Additional factors of relevance to the goal of the study were considered when they were initiated by the subject.

Both the introduction by the researcher and the interviews were recorded and later transcribed. Following each interview brief notes were made about the main topics discussed in each session; these later served as an initial guide to the researcher as the process of analysis was initiated.

Analysis: Content analysis of the written data derived from the interview tapes was subsequently undertaken.

Two independent assessors assisted in the identification and definition of categories; four additional assessors were used to examine the transcripts and identify material which fell within each category. Each assessor had a minimum of two years' experience in the treatment of soft tissue lesions (range: 2 to 6 years; mean 3.5 years) and was currently engaged in the use of electrophysical agents.

The following procedure was used, having been derived from the work of Downe-Wamboldt (1992) and Burnard (1991):

1. The text was scrutinised by the researcher.

2. The researcher identified and defined categories within the text; these were submitted to two independent assessors who confirmed their presence within the text.

3. The researcher identified and marked material within each text which related to each category.

4. Four independent assessors, not used in stage two, were supplied with unmarked copies of the transcript of each text and a list of the twelve categories previously identified.

5. Each assessor was supplied with instructions, asking them to scrutinise the text and mark all occurrences of material which fell within each of the categories listed.

6. The researcher compared the transcripts returned by the independent assessors with the original; instances of agreement and disagreement were noted.

7. When there was 90% or more agreement on all statements relating to a category, that category was considered to be present in the text.

8. Statements relating to each category were abstracted from the text; only those statements agreed upon by the researcher and all four assessors as being representative of a category were used for analysis.

9. Statements falling within each defined category were examined in further detail.

Appendix 6 contains a full list of the statements identified at stage 8 of the above procedure.

The data subsumed under each category identified during the above procedure was subsequently examined to identify the key concepts that these physiotherapists used to determine their use and selection of ultrasound, shortwave diathermy and laser in the treatment of soft tissue lesions. Descriptive statistics were used to provide information about the distribution and ranking of data.

The reliability of the processes used in content analysis had to be established in order to avoid bias in the results. Categories and symbols were fully and carefully defined and the coding of data fully described. Both intra-rater and inter-rater reliability were assessed through the repeated examination of a small part of the data derived from the interviews; such pilot work served to establish the level of agreement between assessors and the stability of assessment by individual assessors over time. Reliability was established through the use of percentage agreement (Krippendorff, 1980: Webber, 1985; Polit and Hungler, 1991). Both inter- and intra-rater reliability were assessed for phase II of this study, using data extracted from three interviews. Inter-rater reliability was assessed on a single occasion using four assessors and demonstrated an agreement level of 89%. Intra-rater reliability was assessed across a three month period, using the same four assessors, and demonstrated an agreement of 91%; both figures represent a level of reliability which is sufficient for the present purposes.

Results: Ten physiotherapists agreed to participate in the study; time since qualification varied from 3 to 38 years (mean 15.7 years; mode 12 years) and experience in the use of electrophysical agents from 6 months to 14 years (mean 7.3 years; mode 7.5 years). All subjects had access to ultrasound and shortwave diathermy equipment and four had access to laser units. Other electrophysical agents were available to all ten subjects but were not discussed in this study. All subjects were currently treating soft tissue lesions on a daily basis.

The use of probes provided a wealth of information which was subsumed under twelve categories, identified by the researcher and confirmed by the independent assessors. They were as follows:

1. Soft tissue problems benefiting from treatment *
2. Dosage parameters and selection *
3. Progression and number of treatments *
4. Factors affecting selection of agent and dosage *
5. Therapeutic effects
6. Adverse reactions to electrotherapeutic agents
7. Electrotherapeutic agents as adjunct *
8. Sequential use of agents
9. Similarities and differences between agents

10. Attitude to and beliefs about electrotherapeutic agents

11. Placebo factors

12. Sources of information about agents

Those categories marked with an asterisk (*) arose directly from the introduction of the probe topics whilst the remainder were initiated by the interviewees. Each category will be discussed in detail.

1. Soft tissue problems benefiting from treatment

The interviewees (n=10)[1] identified a total of twenty five problems which they believed to indicate the use of ultrasound, shortwave diathermy or laser. These fell into three categories: (1) named conditions, (2) signs and symptoms noted during assessment of patients and (3) specific, anatomical structures. A total of 63 statements were made.

Named Conditions: Fourteen soft tissue conditions were identified as suitable for treatment with either ultrasound (s=12)[2], laser (s=7) or shortwave diathermy (s=6); these are listed in table 6. Both closed (s=19) and open lesion (s=6) were cited.

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[1]Key: number of interviewees n = (1)

[2]Key: Number of statements s = (1)

Ultrasound was believed by this group to be useful for the greatest number of conditions whilst continuous shortwave diathermy was believed to be least useful. The data indicated that nonthermal techniques were preferred as heating was believed to exacerbate many inflammatory conditions and ultrasound was selected most frequently as the physiotherapists felt that they had greatest understanding of this area.

Table 6. Named lesions treated with ultrasound, shortwave diathermy and laser (n = 10).

ULTRASOUND s=12	LASER s=7	PSWD s=4	CSWD s=2
muscle tears	muscle tears	haematomas	capsulitis
haematomas	pressure sores	pressure sores	pelvic inflammatory disease
sprains	diabetic ulcers	sprains	
strains	wounds , cuts		
bursitis	surgical wounds		
supraspinatus tendinitis	inflammation of dural sheath		
Dupuytren's contracture			

Signs / symptoms: Five signs were cited as indicators for treatment with US, SWD or laser. These were swelling, crepitus, bruising, spasm and 'tightness' (s=8); no indication was given as to the nature of the latter. Pain was the primary symptom identified by this group, who considered it an indication for treatment with ultrasound (s=2) and laser (s=2); pulsed shortwave diathermy was used by two interviewees for the relief of treatment soreness following physical procedures (s=3).

Structures: Nine interviewees identified anatomical structures which they considered suitable for treatment with either US or laser. These were tendon (s=10), ligament (s=7), muscle (s=4) and scar tissue (s=2). Ultrasound therapy was considered an appropriate treatment for all four types of tissue injuries whilst laser was considered appropriate for ligament and tendon lesions only.

In addition to identifying conditions, signs and symptoms and structures which were deemed appropriate for treatment with these agents, three interviewees identified a number of soft tissue problems for which they believed treatment to be inappropriate. The areas identified were pain (PSWD; s=1), swelling (PSWD; s=1), bursal lesions (laser; s=1), back lesions (CSWD; s=2, PSWD; s=2) and neurological lesions (US; s=2). These interviewees believed that these lesions were unaffected by electrophysical treatments, with the possible exception of neurological problems which were sometimes believed to worsen with such intervention.

2. Dosage parameters and selection

Intensity of dosage (s=30), duration of treatment (s=10) and the use of pulsing to modify a dosage (s=9) were described. Additional information was provided about the selection of dosages in terms of wavelength, frequency and experience.

Intensity of dosage: Fourteen statements reflected a belief that the intensity of dosages should be mild, low or very low; this principle was said to be employed by the interviewees when selecting the dosage parameters for SWD (s=5), PSWD (s=1), US (s=4) and laser (s=2). All but one of the remaining statements reported that <u>all</u> agents were used at very low intensities; one statement, however, reported that PSWD was normally used at high intensities.

Additional statements about dosage intensity (s=15) described in detail the parameters used most frequently when treating a variety of soft tissue lesions. Most statements indicated the highest dose the therapist used in practice and were specific to each agent. Three interviewees stated that they used the same treatment parameters irrespective of the type of lesion; others (n=5) reported using slightly higher doses for chronic lesions.

Duration of treatment: Duration of treatments varied according to the agent and the chronicity of the lesion. Ultrasound and laser were given for shorter periods of time, ranging from 2 to 6 minutes depending on the size of the lesion, while SWD was given for up to 20 minutes. Chronic lesions received, on average, double the treatment time given to acute lesions. There was disagreement about the relationship between length of treatment and the depth of the lesion; one interviewee reported that time was increased for deeper seated lesions while a second stated that depth made no difference to this parameter.

Use of pulsing: Dosage was varied by the implementation of pulsing when using US (s=7) and laser (s=2). Again, chronicity affected choice; the pulsing ratio was increased for acute lesions and reduced for subacute and chronic lesions. Pulsed SWD was preferred to the continuous form, but no information was supplied about the pulsing ratios used.

Wavelength and frequency: The importance of selecting the appropriate wavelength or frequency for laser and US was mentioned by three interviewees, though no details were given about their choices. Despite noting the importance of choice, none of those using laser were able to do so owing to the design of their equipment.

Experience: Personal experience was regarded as an important factor in governing selection of treatment agents and dosages by eight interviewees (s=10). Six based their selection on this factor alone.

A major factor affecting selection was the availability of equipment. Two interviewees stated that their choice of dosage parameters was limited by the equipment available to them and three reported difficulty in determining dosages as the output markings on the available equipment provided little guidance as to the dosage actually received by the patient. All those using laser reported difficulty in selecting dosage parameters due to lack of knowledge.

3. Progression and number of treatments

Both the progression of treatment and appropriate number of sessions were addressed by eight interviewees (s=21).

Progression of treatment: The two major factors reported to govern the progression of treatment were verbal reports of changes in signs, symptoms and function by the patients and the observed lesion response. Treatments were progressed by this group in terms of time or intensity (s=5), with preference being expressed for increasing one or other of the two, with the choice depending on personal experience and the agent in question.

Number of treatments: Statements about the frequency of treatment fell into two categories; interviewees either employed a very small number of treatments (2-4) or a considerably larger number (10-12 treatments). Those who used the smaller number believed that if the treatment had not been seen to be effective in this period it was unlikely to be efficacious, whilst those using the longer periods believed that the longer time was necessary if results were to be seen.

4. Factors affecting selection of agent and dosage

All interviewees (n=10) cited factors which affected their selection of treatment agent or dosage (s=63); these are presented in table 7, ranked according to frequency of reporting. The two most influential factors influencing selection were the chronicity and size of the lesion; together they accounted for 49 % of the statements.

Table 7. Factors reported to affect treatment selection (n=10).

FACTORS	NUMBER OF STATEMENTS
Chronicity of lesion	21
Size of lesion	10
Depth of lesion (closed lesions)	6
Symptoms	6
Prior experience of therapist	5
Contraindications to use of agent	5
Alternative to other techniques	3
Tissue type	2
Ease of use	2
Temporal factors	2
Patient preference	1
	total = 63

This group of interviewees reported that ultrasound was less suitable for open than closed lesions due to the need for a coupling medium during application and the opportunities this provided for introducing infection into open wounds. Laser and, to a lesser extent, pulsed SWD were reported to be more appropriate treatments for open lesions as they could be applied using a non-contact technique. Pulsed shortwave diathermy was advocated for large and more irregular lesions and laser for smaller, clearly localised problems.

5. Therapeutic effects

All interviewees (n=10) identified both physiological and physical effects which they believed to arise in the treatment of soft tissue lesions.

Physiological effects: ten physiological effects were identified by eight interviewees; these are reported, ranked in order of frequency of reporting in table 8.

Table 8. The physiological effects reported to result from the use of ultrasound, shortwave diathermy and laser (n=8).

PHYSIOLOGICAL EFFECTS	NUMBER OF STATEMENTS
Relief of pain	10
Circulatory changes	10
Increase fluid absorption	5
Modify scar tissue	4
Modify metabolism	2
Alter muscle tone	2
Increase tissue elasticity	2
Cellular calcium exchange	1
	Total = 36

a little more than

The two most frequently identified, which accounted for 50% of the total statements, referred in equal numbers to the relief of pain and circulatory changes. All three agents were accredited with producing the last two physiological effects when used to treat soft tissue lesions.

Physical effects: Six interviewees described physical effects which they believed to result from the use of US, SWD or laser; these were changes in tissue temperature (s=6), massaging effects (s=3) and mechanical effects (s=1). Changes in temperature were believed to arise from the use of all three agents. Two interviewees suggested that pulsing US or SWD eliminated any heating effects normally produced by these agents when used in their continuous forms. In contrast, a third stated that both continuous and pulsed forms of both agents would produce heating of the tissue, though to different degrees.

Both massage and mechanical effects were attributed to ultrasound by four interviewees, who reported that it produced these effects through gentle vibration of the tissue.

All interviewees who suggested physical effects believed that these underlay the occurrence of one or more of the physiological effects.

6. Adverse reactions

Though the topic of adverse reactions to electrophysical agents was not specifically raised through the probes, nine of the ten interviewees discussed their occurrence. Adverse effects were experienced with US (s=12), CSWD (s=3), laser (s=3) and PSWD (s=1).

Adverse reactions to ultrasound: The most common adverse effect reported was the occurrence of sharp local pain during the use of US, over the point of insonation (n=7; s=8). Four interviewees attributed the problem to the reflection of sound waves over bony points, two having experienced the problem when treating the elbow. Others suggested that it was due to lack of full contact between the treatment head and the part or inadequate movement of the applicator over the skin.

Other adverse effects reported were local tingling during treatment (s=1), aching following treatment (s=1) or 'discomfort' (s=1). The nature of the latter was unspecified. One interviewee stated that no adverse effects had been experienced with the use of US.

Adverse reactions to CSWD: The adverse effects arising from the use of CSWD were reported as burning (s=1), local aching following treatment (s=1) and general giddiness immediately following the application of the agent (s=1). One interviewee stated that no adverse effects had been experienced during usage of this agent.

Adverse reactions to PSWD: Few had experienced any adverse effects following the use of PSWD, with a single interviewee reporting having experienced one occurrence of 'bone ache' following its usage. Three others stated that, in their experience, PSWD had never caused any adverse effects.

Adverse reactions to laser therapy: The adverse effects experienced with the use of laser were increased inflammation (s=1), increased pain (s=1) and discolouration of pigmented skin (s=1). One interviewee stated that no adverse effects had been experienced with the use of laser thus far.

7. Electrotherapeutic agents as adjunct

All interviewees (n=10) suggested that US, SWD and laser might be used in an adjunct capacity in association with other physiotherapeutic techniques, other forms of electrophysical agent or both. The view that agents should not be used alone was further emphasised by seven interviewees (s=10) who, though giving no indication of possible additional treatments, stated that effects were cumulative and electrophysical treatments alone were inadequate to manage soft tissue lesions.

Six interviewees (s=12) suggested that other physiotherapy techniques such as ice, strapping, frictions, mobilisations and the giving of advice could be combined with electrotherapy. The concept of combining electrophysical agents with one another was discussed by seven interviewees; four were strongly in support of the practice but were specific about the combinations found useful whilst three were against the practice in any form. Those in favour of combining agents listed the following pairs: US and laser (s=4), US and interferential therapy (s=3) and US and PSWD (s=2). Those against the practice of combining electrophysical agents justified their stance on the basis of loss of information; they claimed that feedback about the efficacy of individual electrophysical treatments would be lost if more than one was used.

8. Sequential use of agents

Sequencing of agents was reported frequently by the interviewees (s=15). Whilst only a limited number endorsed the concept of combining electrophysical agents during a single treatment, six interviewees indicated that a switch from one agent to another during the course of a treatment programme could be beneficial under a variety of conditions.

Reasons for the use of sequencing fell into two categories. Firstly, interviewees suggested that the perceived benefits might be due to interaction between agents; examples included switching from US to laser and interferential therapy to PSWD. Secondly, two interviewees suggested that patients often appeared to plateau in their response to a single agent and that a change could facilitate further tissue repair.

Further reasons given for sequencing were difficulty in determining the precise nature of many soft tissue lesions (for example, soft tissue versus joint injury) and the belief that patients responded differently to individual agents. Sequencing was then needed in order to identify the most effective treatment.

9. Similarities and differences between agents

Interviewees (n=8) held varied views about the similarities and differences which existed between the agents, some believing that certain agents were interchangeable whilst others did not.

Similarities: Six interviewees stated that agents were similar or interchangeable (s=8). The following pairs of agents were reported to be interchangeable: PSWD and US (s=3), laser and US (s=3), PSWD and SWD (s=2), SWD and US (s=1), PSWD and pulsed microwave diathermy (s=1) and PSWD and laser (s=1). One interviewee suggested that all three agents under consideration were fully interchangeable.

Differences: Reports about the differences existing between agents were less specific in nature, with six interviewees simply stating that they existed. Most considered that some agents were interchangeable whilst others were not; one interviewees only thought that none of the agents considered were interchangeable.

Two interviewees made contrary statements which reflected their difficulty in this area; one suggested that pulsed shortwave diathermy and microwave diathermy were interchangeable despite a prior statement suggesting that no agents were interchangeable and a second suggested that the effects of SWD and PSWD were dissimilar but then qualified the statement by suggesting that they acted in the same way but to differing degrees. Such statements highlighted the difficulties interviewees experienced with regard to this subject, a subject which was raised spontaneously during discussion.

10. Attitude to and beliefs about electrotherapeutic agents

All interviewees (n=10) volunteered information which reflected both their confidence in the usage of electrophysical agents in the management of lesions and their doubts and reservations about its efficacy.

In this study, a greater number (n=8) expressed doubt about the efficacy of electrophysical agents in the management of soft tissue lesions than expressed confidence (n=6), though a greater number of statements were made expressing confidence in treatments. Both confidence and doubts were expressed about the use of all agents under consideration. Most confidence was reported with respect to the use of laser despite only four interviewees having access to it (s=5). This was followed, in rank order, by PSWD (s=4), US (s=4) and lastly SWD (s=2). Most doubt was actively expressed about US (s=3); this was followed by PSWD (s=2), SWD (s= 1) and laser (s=0).

Four interviewees discussed the clinical implications of omitting electrophysical agents from a treatment package and all expressed the view that omission would make little difference to the final outcome. Three statements reflected the decision of one subject to omit such treatments during her pregnancy, fearing for the safety of the foetus. One subject stated that she did not always take such equipment out into the community and the remaining two noted that they felt that they could still treat most patients adequately without the use of electrophysical agents.

Reservations about the efficacy of electrophysical treatments in general were also expressed; three interviewees suggested that electrophysical agents could be slow to produce results and suggested that the response seen might be due to natural processes rather than the agent, whilst a further three indicated that treatment results were frequently erratic.

11. Placebo factors

Placebo, or psychologically mediated, effects were considered an important part of treatment with electrophysical agents. All interviewees spontaneously addressed this area. Many statements made by this group (s=20) cast doubt upon the physiological efficacy of the agents, suggesting that changes could be largely due to placebo effects.

In addition a number of interviewees reported that they made specific use of the placebo effects of US, SWD and laser in certain situations; fourteen statements referred to the use of electrophysical treatments to gain patient co-operation and increase patient satisfaction.

12. Sources of information about agents

All but one interviewee (n=9) discussed sources of information used to inform their use and selection of electrophysical agents.

A mixture of sources emerged from the interview data, with literature distributed by the manufacturers emerging as the most frequently consulted. Such literature was referred to by eight of the nine interviewees (s=12), of whom four expressed some disquiet about the reliability and quality of the source. Information gained through undergraduate education was the second most commonly mentioned information resource (s=7). These two together accounted for 59% (19 of the 32) of the statements about the sources of information.

Books and journals (s=5), postgraduate courses (s=4), discussion with colleagues (s=2) and in-service training (s=1) provided the remaining sources of information.

Four interviewees, however, felt that they had gained most information about the usage of electrophysical agents through their own experience.

These therapists observed others using the equipment, experimented with dosages and relied on patient reports and observed tissue response for guidance.

Section II. Chapter 5.

PHASE III: A SURVEY TO EXAMINE THE CLINICAL USE OF ULTRASOUND, SHORTWAVE DIATHERMY AND LASER IN ENGLAND

The purpose of the third phase of the study was to investigate and compare usage of ultrasound (US), shortwave diathermy (SWD; continuous C, pulsed P) and laser by a random sample of physiotherapists in out-patient units within the National Health Service and to obtain information about a number of factors influencing the selection of these modalities. A survey was planned to obtain this information; it focused upon the following aspects:

* frequency of usage of laser, ultrasound and shortwave diathermy
* the types of soft tissue lesions treated with electrotherapy
* the usage of electrotherapy treatments in combination with other forms of electrotherapy and physical therapies
* beliefs about the similarities and differences in effects between electrotherapy treatments
* beliefs about the placebo effects of electrotherapy
* use of the placebo effects of electrotherapy
* sources of the knowledge base of physiotherapists

I. DEVELOPMENT WORK

A number of surveys have been reported which examined the use of ultrasound (DWH, 1980a; ter Haar et al, 1987; Lindsey et al, 1990), shortwave diathermy (DWH, 1980b; Lindsey et al , 1990) and laser (Baxter et al, (1991; McMeekan and Stillman, 1993) in clinical practice both in Britain and abroad. The majority examined the use of a single agent and none covered all the aspects identified in the pre-pilot and pilot studies as of importance to clinicians in Britain at the present time. A new schedule was therefore developed which addressed both the aspects highlighted in the literature and by the pilot work; a copy is provided in Appendix 7.

Development of source material

Because of the limited information in the literature, the majority of the items used in the schedule were derived from the pilot work with experienced therapists who use electrotherapy.

Selection of items for the questionnaire

In order to select appropriate items for the questionnaire, a list of objectives was drawn up which reflected the purpose of the investigation. This list is presented on page 208.

Format and type of questions

Closed questions were used to elicit factual information such as the respondents professional grade, the equipment available to them, frequency of usage, conditions treated and sources of information used to inform clinical practice. In addition rating scales were used to elicit information about their beliefs concerning the placebo effects of physiotherapy treatments, the similarities and differences in the clinical effects brought about by the agents in question and the use of electrophysical agents as adjunct treatments.

Open questions were employed to a lesser extent; examples included asking the respondents to identify the soft tissue lesions they believed to respond to electrophysical agents alone, to list the combinations of agents which they believed to be useful when used in conjunction during a single treatment and to identify the factors affecting their selection of one agent if they believed the clinical effects of two or more agents to be similar.

Scaling of responses

A number of different types of scales were used to score the items developed, the types used depended on the form of the individual questions.

Categorical Scales: A number of questions used in the survey required categorical judgements, requiring the correspondent to answer either 'yes/no' or to check a list and tick the correct response.

Continuous Scales: Many questions presented in this survey required responses which fell along a continuum as opposed to the simpler categorical scales noted above. Adjectival, or Likert, scales use a form of direct estimation and employ a sequence of descriptive terms to quantify the subject's response. Such scales were selected for use in this study as they are easily understood and have high face validity for the subject (Streiner and Norman, 1989; Oppenheim, 1992).

Each scale used in this survey consisted of four or five steps, or points, the precise number being determined through piloting of the schedule and the nature of the question. Nishiatso and Torri (1970) suggest that more increments may increase the reliability of a scale but both pilot work and the literature suggested that the number of increments used were adequate for the purposes of this study. On each occasion the scale took the form of agreement or disagreement with a statement. The scales normally consisted of the following points: strongly agree, agree, uncertain, disagree and strongly disagree.

Ordinal Scales: Two questions required the subject to make use of ordinal scaling; they were asked to rank a series of statements in response to a question. These questions referred to the perceived placebo effects of each agent under consideration and the value placed by the respondent upon a number of learning opportunities.

Pilot work

The schedule was piloted, using a convenience sample of six qualified physiotherapists who had a minimum of two years experience in the use of electrophysical agents. Each was provided with a copy of the schedule and a written request in which they were asked to complete the questionnaire and provide feedback about the relevance and breadth of content and the structure and intelligibility of the instructions and questions. Following the return of the completed questionnaires and comments, a number of alterations were made to the text; these involved changes to the structure of the questionnaire to allow further space for responses to the open questions, the removal of the 'uncertain' category from the scale used to examine the use of electrotherapy as an adjunct treatment and adaptations to the wording used to introduce questions requiring rank ordered responses.

The amended questionnaire was then re-piloted, using a judgement sample of six further physiotherapists. This group reported no further difficulties.

Reliability and validity

Important factors in establishing the reliability of phase III of this study were adequate sample numbers, satisfactory sampling techniques, a high return rate and accurate information. The total number of physiotherapists using electrotherapy in the management of soft tissue lesions is unknown; however, following discussion with a statistician about the design to be used and the outcome of the pilot work (phases I and II), a sample of 100 was considered adequate for this study. The sampling technique used involved stratified randomization; stratification was considered necessary to avoid any regional effects resulting from factors such as the influence of local specialists, training initiatives or sales drives. In addition, whole departmental populations were drawn from each region in order to ensure that all clinical grades were represented. High return rates were encouraged through personal contact with departments, the use of information sheets, confirmation of personal anonymity and attention to the validity of the questions.

The reliability of the questionnaire was evaluated using the test-retest method; a convenience sample of ten subjects filled in the questionnaire on two occasions separated by a two week interval. The mean percentage agreement between the two sets of results was 94%, indicating that the tool was sufficiently reliable for the present purpose. There was 100% agreement between the two trials for factual questions such as the clinical grade of the subject and the types of equipment available to them.

Categorical questions concerning lesions treated during the last six months resulted in 96% agreement. Ranking of information concerning the placebo effects ultrasound, shortwave diathermy and laser and of the factors most influencing learning achieved 93% and 92% agreement respectively. The remaining questions required answers which were rated along a continuum, involving either four or five steps. All but one disagreement in response to these questions involved the subject in rating the answer one gradation above or below the initial response; for example, a number of answers shifted from 'agree' to 'strongly agree'.

The schedule was examined for face and content validity. Face validity was examined at the pilot stage; all physiotherapists reported finding the questions acceptable and relevant to clinical practice and the stated purpose of the survey following revision, and the instructions clear and unambiguous. As the questions asked in this survey related directly to the property under investigation, the validity of the schedule was inherent within its content. The use of exploratory interview studies as the primary source of items contributed greatly to the content validity of the questionnaire; during piloting of the questionnaire, experienced clinicians were asked to report on the clinical relevance of the items presented and note any omissions they considered important. No difficulties were reported.

Analysis

Descriptive statistics were used on the data generated. In addition, content analysis was used to categorise the material obtained from the open questions.

II. THE CONDUCT OF THE SURVEY

The use of ultrasound, shortwave diathermy and laser by practising clinicians throughout England was examined to obtain information about the selection of these agents and the factors affecting choice.

__Design__: A survey method, involving the use of a postal questionnaire

__Subjects__: A random sample of approximately 100 subjects was required for this study.

In order to accommodate any regional variations in the use of electrotherapy, a stratified technique was used to distribute the sample across England. All health districts within each Regional Health Authority were allocated a number (in 1992); one district was randomly selected from each region through the use of a random numbers table. The local physiotherapy district manager was asked to identify a single physiotherapy out-patient department which might be contacted and for permission to approach staff within that unit. The departments identified had to fulfil the following criteria:

- treat patients with soft tissue lesions on a regular basis
- have available two of the three agents in question (US, SWD, laser)
- not be specialist units (eg. paediatric, neurological)

A total sample of those using electrotherapy treatments was drawn from each department in order to ensure full representation of all grades of staff.

<u>Materials</u>: Schedules with open and closed questions

Letters of introduction; information sheets

<u>Procedure</u>: Questionnaires were sent out to physiotherapists in all 14 regions of the National Health Service in England. Each department was contacted by letter (see Appendix 8) and the nature and purpose of the study explained. The departmental superintendent was subsequently contacted by telephone and permission sought to send a schedule to each member of staff currently using electrotherapy in the management of soft tissue lesions. All schedules were sent to the superintendents, who agreed to distribute them. These were either returned by the superintendent or by the each member of staff individually depending on the preferences of the department. Stamped, addressed envelopes were provided for replies.

Each questionnaire was accompanied by a letter of explanation and all subjects were assured of personal anonymity in all reports and confidentiality of information provided (Appendix 9). In addition it was stressed that the researcher was interested in the views and practices of each individual and that there were no right or wrong answers. Respondents were asked not to confer with other therapists prior to filling in the form in order to avoid the introduction of group bias.

Non-respondents were followed up on two occasions as necessary; firstly a verbal reminder by telephone and secondly a written reminder was used.

Analysis: All returned questionnaires were coded and the data analysed using descriptive statistical methods. Both the raw data and codings used are contained in Appendix 10.

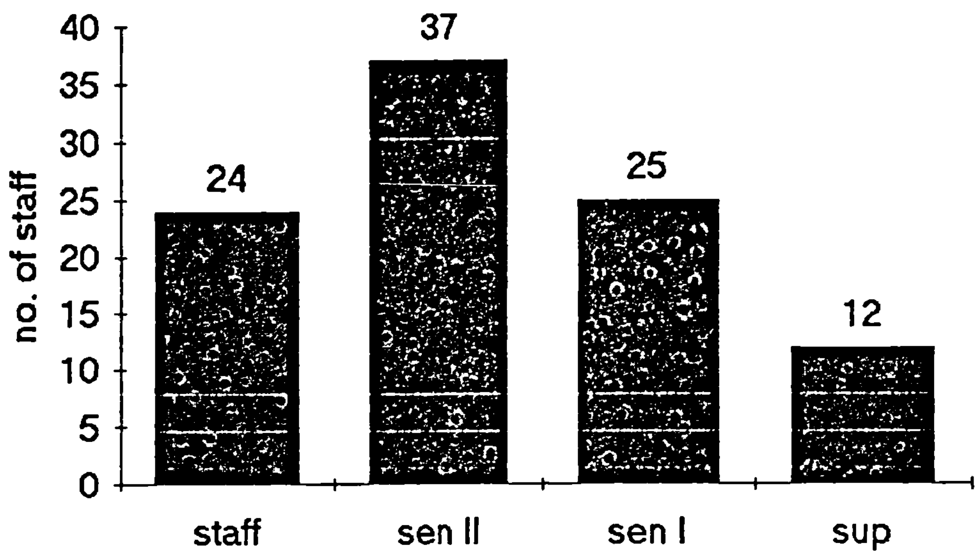
Results:

1. **Respondents**: A sample of 111 subjects was contacted and invited to participate in the study. They came from 14 physiotherapy departments across England; the number employed in each varied between 2 and 17 (mean: 7.7). Ninety nine questionnaires were returned, giving a response rate of 89%. One returned form was incomplete and was not included in the final analysis. Data from 98 questionnaires was therefore analysed.

The 12 non-respondents were followed up; in five cases the subjects were ill during the entire period of the study, two were discovered to be therapy aids and were therefore not eligible to complete the questionnaire and five non-respondents remained unidentified.

All respondents were chartered physiotherapists. Figure 6 shows the distribution of respondents according to clinical grade (staff, senior II, senior I and superintendent).

Figure 6. Distribution of respondents according to clinical grade (n=98)



The majority of respondents (88%) were graded as senior 2 or above; this compares favourably with a national figure of 80.8% in 1992 (Walker and Lee, 1993), suggesting that the sample obtained was not unrepresentative of the work force as a whole.

2. **Availability of equipment:** All respondents had access to continuous ultrasound (CUS) and pulsed ultrasound (PUS); 98% had access to pulsed shortwave diathermy (PSWD) and 85% to continuous shortwave diathermy (CSWD) (98%). Only 33% had access to laser.

Twenty seven respondents had access to all five agents; two reported access to two agents only (CUS and PUS). Of those having access to four agents (n=61), 56 lacked access to laser and five to CSWD.

3. **Frequency of usage:** All respondents provided information about the frequency with which they had used CUS, PUS, CSWD, PSWD or laser in the treatment of soft tissue lesions over the last six months.

Ultrasound: Table 9 shows the frequency of reported usage of CUS and PUS for soft tissue lesions over a six month period; this agent was available to all respondents in both its continuous and pulsed forms (n=98).

Table 9. Frequency of reported usage of CUS and PUS for soft tissue lesions over the previous six months (n=98)

FREQUENCY OF USAGE	CUS % of respondents	PUS % of respondents
Most days of the week	27	51
1-2 days per week	29	25
2-3 times per month	13	14
less than once a month	12	6
never	19	4

These results indicate that pulsed ultrasound was used more frequently than the continuous form with 76% of respondents reported using PUS more than once a week whilst only 56% used CUS as frequently.

The results were examined to see if there were any differences between the reported usage of ultrasound by respondents of differing clinical grades and the results are presented in table 10; it should be noted that the number of respondents in each category is different.

Table 10. Percentage of respondents at each clinical grade reporting use of CUS and PUS once a week or more during a six month period

AGENT	STAFF n=24	SENIOR II n=37	SENIOR I n=25	SUPER n=12
CUS	46%	62%	48%	42%
PUS	87.5%	78%	56%	83%

(Key: super = superintendent)

The extended Chi squared test was used to examine whether the differences between the grades were significant and it was found that the only significant difference lay between the numbers of staff and senior II groups using PUS.

Shortwave diathermy: Tables 11 and 12 show the reported frequency of usage of CSWD and PSWD respectively for the treatment of soft tissue lesions over a six month period; CSWD was available to 83 and PSWD to 96 respondents.

Use of the pulsed form was again reported more frequently; 72% of the respondents reported using PSWD more than once a week whilst only 16% used the continuous form as frequently. These reports indicate that neither agent was used as frequently as ultrasound.

Table 11. Frequency of reported usage of CSWD for soft tissue lesions over the previous six months (n= 83)

FREQUENCY OF USAGE	% OF RESPONDENTS
Most days of the week	2
1-2 days per week	14
2-3 times per month	12
less than once a month	24
never	47

Table 12. Frequency of reported usage of PSWD for soft tissue lesions over the previous six months (n=96)

FREQUENCY OF USAGE	% OF RESPONDENTS
Most days of the week	39
1-2 days per week	33
2-3 times per month	11
less than once a month	10
never	6

The extended Chi squared test was again used to examine whether there were any differences in the reported usage of shortwave diathermy by respondents of varying clinical grades and the test demonstrated no significant differences.

Laser: Table 13 shows the reported level of usage of this agent by this group; laser was available to 32 respondents only. This table demonstrates that half the respondents having access to laser reported using it in the treatment of soft tissue lesions once a week or more. However, almost a third of the respondents with access to laser stated that they used the agent less than once a month. It was not possible to use any statistical tests to examine the differences in usage between the different clinical grades as the numbers in each category were too small.

Table 13. Frequency of reported usage of laser for soft tissue lesions over the previous six months (n=32)

FREQUENCY OF USAGE	% OF RESPONDENTS
Most days of the week	25
1-2 days per week	25
2-3 times per month	18
less than once a month	16
never	16

4. Types of lesions treated: Respondents provided information about their use of CUS, PUS, CSWD, PSWD or laser to treat the signs and symptoms of inflammation, closed lesions and open lesions during the preceding six months. The results are first presented separately for ultrasound, shortwave diathermy and laser and then drawn together in summary.

Ultrasound: All respondents (n=98) had access to both pulsed and continuous ultrasound.

Signs and symptoms: Respondents reported their usage of CUS and PUS in the management of pain, muscle spasm (linked to pain), oedema, scarring or haematomas and bruising during the preceding six months; the results are presented in table 14.

Table 14. Percentage of respondents reporting use of CUS and PUS to treat the signs and symptoms of inflammation (n=98)

SIGNS & SYMPTOMS	CUS % of respondents	PUS % of respondents
Pain	36	63
Spasm	8	20
Oedema	15	43
Scarring	65	37
Haematoma/bruising	11	57

Again this data highlights the greater reported use of pulsed energy. When symptoms were ranked according to the percentage of respondents reporting usage, scarring was most frequently treated with a continuous beam while pain and haematomas or bruising were most frequently treated with a pulsed beam of sound. When the reports of each clinical grade of staff was examined separately, it was found that the ranking of top two symptoms was identical for all grades for both forms of ultrasound treatment.

Closed lesions: Respondents reported their use of CUS or PUS in the management of muscle, ligament and tendon lesions, bursitis or fascial tears during the preceding six months and the results are presented in table 15. These respondent again reported using PUS more frequently than CUS.

When the results shown are ranked the order assumed in each listing is identical, the order being ligament tears, tendon lesions, muscle tears, bursitis and fascial tears. With only one exception, ranking remained identical when each grade of clinical respondent was examined separately; senior I respondents ranked the use of CUS to treat muscle lesions first.

Table 15. Percentage of respondents using CUS and PUS to treat closed soft tissue lesions (n=98)

CLOSED LESIONS	CUS % of respondents	PUS % of respondents
Muscle lesions	38	63
Ligament tears	45	79
Tendon lesions	40	69
Bursitis	27	44
Fascial tears	19	29

Open lesions: Respondents reported use of ultrasound in the management of ulcers, pressure sores, surgical or traumatic wounds during the preceding six months; these results are reported in table 16.

Table 16. Percentage of respondents using CUS and PUS to treat open soft tissue lesions (n=98)

OPEN LESIONS	CUS % of respondents	PUS % of respondents
Ulcers	0	6
Pressure sores	0	4
Surgical wounds	3	17
Traumatic wounds	6	19

When ranked, the order was the same for both forms of ultrasound, being traumatic wounds, surgical wounds, ulcers and pressure sores. Surgical wounds and traumatic wounds were ranked either first or second by all clinical grades of respondents; however, no respondents of Senior 1 grade reported using CUS for open lesions of any type during the previous six months.

Summary: This sample of physiotherapists reported greater use of pulsed ultrasound in the treatment of all three categories of clinical problems examined. Few respondents reported using ultrasound to treat open lesions, whilst greatest use was reported in connection with closed injuries.

Shortwave diathermy: Eighty three respondents reported access to continuous shortwave diathermy (CSWD) and 96 reported access to pulsed shortwave diathermy (PSWD).

Signs and symptoms: Subjects reported their use of CSWD and PSWD in the management of pain, muscle spasm (linked to pain), oedema, scarring or haematomas and bruising during the preceding six months. The results are presented in the tables 17 and 18.

This group of respondents reported making much greater use of pulsed shortwave diathermy than its continuous counterpart.

Table 17. Percentage of respondents reporting use of CSWD to treat the signs and symptoms of inflammation (n=83)

SIGNS & SYMPTOMS	% OF RESPONDENTS
Pain	28
Spasm	11
Oedema	1
Scarring	1
Haematoma/bruising	2

Table 18. Percentage of respondents reporting use of PSWD to treat the signs and symptoms of inflammation (n=96)

SIGNS & SYMPTOMS	% OF RESPONDENTS
Pain	69
Spasm	32
Oedema	68
Scarring	4
Haematoma/bruising	78

When symptoms were ranked according to the percentage of respondents reporting usage, it was noted that pain was most frequently treated with a continuous beam (28% of respondents). However haematomas and bruising (78% of respondents) are most frequently treated with pulsed energy, with pain followed closely behind (69% of respondents reporting usage). The rank order identified for pulsed shortwave diathermy (haematoma/bruising, pain, oedema, spasm and scarring) is identical to that for pulsed ultrasound.

When the reports of each clinical grade of staff was examined separately, it was found that the first two rankings (pain and spasm) were identical for all grades for continuous shortwave diathermy. With respect to PSWD, all clinical grades ranked the treatment of haematomas and bruising either first or second.

Closed lesions: Respondents reported their use of CSWD or PSWD in the management of muscle, ligament and tendon lesions, bursitis or fascial tears during the preceding six months; results are presented in tables 19 and 20.

Table 19. Percentage of respondents using CSWD to treat closed soft tissue lesions (n=83)

CLOSED LESIONS	% OF RESPONDENTS
Muscle lesions	5
Ligament tears	2
Tendon lesions	2
Bursitis	6
Fascial tears	5

Table 20. Percentage of respondents using PSWD to treat closed soft tissue lesions (n=96)

CLOSED LESIONS	% OF RESPONDENTS
Muscle lesions	65
Ligament tears	46
Tendon lesions	44
Bursitis	50
Fascial tears	26

They again used PSWD more frequently than CSWD. When the results were ranked it becomes evident that bursitis and muscle tears are most frequently reported to be treated with shortwave diathermy of both types; there is, however, a major discrepancy between the reported level of use of the pulsed and continuous forms.

The ranking of lesions according to the usage of CSWD and PSWD remained similar, though not identical, when each grade of clinical respondent was examined separately. Muscle lesions were ranked within the top two places by all groups; bursitis, fascial tears and ligament tears all featured as the second element in the ranking by different groups.

Open lesions: Respondents reported use of CSWD or PSWD in the management of ulcers, pressure sores, surgical wounds or traumatic wounds during the preceding six months. No respondents reported using CSWD to treat opèn lesions and the results of those using PSWD are reported in table 21.

Table 21. Percentage of respondents using PSWD to treat open soft tissue lesions (n=96)

OPEN LESIONS	% OF RESPONDENTS
Ulcers	10
Pressure sores	0
Surgical wounds	24
Traumatic wounds	34

When the list of open lesions were ranked according to the numbers of respondents reporting usage of PSWD, traumatic wounds were most frequently treated with this agent. This is similar to the use of PUS where again traumatic wounds were most frequently treated. Surgical wounds and traumatic wounds remained ranked either first or second by all clinical grades of respondents.

Summary: This sample of physiotherapists again reported greater use of the pulsed agent in the treatment of soft tissue lesions. As in the case of ultrasound, least use appeared to be made of shortwave diathermy to treat open lesions, whist greatest use was reported in connection with the signs and symptoms of inflammation.

Laser: Thirty two respondents had access to laser equipment.

Signs and symptoms: Respondents reported using laser in the management of pain, muscle spasm (linked to pain), oedema, scarring or haematomas and bruising during the preceding six months; results are presented in table 22. When symptoms were ranked according to the percentage of respondents reporting usage, pain was most frequently treated with laser; this was followed by scarring. When the reports of each clinical grade of staff was examined separately, it was found that these two symptoms were identically ranked by all grades.

Table 22. Percentage of respondents reporting use of laser to treat the signs and symptoms of inflammation (n=32)

SIGNS & SYMPTOMS	% OF RESPONDENTS
Pain	69
Spasm	3
Oedema	9
Scarring	44
Haematoma/bruising	25

Closed lesions: Respondents reported using laser in the management of muscle, ligament and tendon lesions, bursitis or fascial tears during the preceding six months and the results are presented in table 23.

Table 23. Percentage of respondents using laser to treat closed soft tissue lesions (n=32)

CLOSED LESIONS	% OF RESPONDENTS
Muscle lesions	53
Ligament tears	56
Tendon lesions	38
Bursitis	34
Fascial tears	15

When results are ranked, ligament tears assume the highest ranking whilst the remaining lesions retain their positions. Examination of the data for each clinical grade showed that muscle lesions were ranked either first or second by all groups.

Open lesions: Respondents reported use of laser in the management of ulcers, pressure sores, surgical wounds or traumatic wounds during the preceding six months; table 24 provides details.

Table 24. Percentage of respondents using laser treat open soft tissue lesions (n=32)

OPEN LESIONS	% OF RESPONDENTS
Ulcers	25
Pressure sores	28
Surgical wounds	25
Traumatic wounds	25

Approximately a quarter of all respondents having access to laser used the agent in the treatment of all forms of open lesions listed. This is a greater level of usage than for any other form of treatment being assessed, though it should be noted that the numbers having access to laser were smaller (n=32).

When the list of open lesions were ranked according to the numbers of respondents reporting usage of laser, three lesions (ulcers, surgical wounds and traumatic wounds) all ranked equally with 25% of respondents reporting usage; pressure sores ranking first with a small increase in usage to 28%. Surgical wounds, pressure sores and ulcers were all ranked first by one or more clinical grade of respondents; however, as there was little difference between the level of usage for each type of lesion, these differences are inconsequential.

Summary: Fewer respondents had access to laser than other agents but the percentage making use of the equipment was greater for open lesions. Slightly less use was made of laser in the management of closed lesions and the signs and symptoms of inflammation than was made of the pulsed forms of ultrasound and shortwave diathermy but more than the continuous forms.

A Comparison of the use of ultrasound, shortwave diathermy and laser:

The following tables, 25 to 27, compare the use of each agent by examining the two problems most frequently reported to be treated with each.

Table 25. A comparison of the % of respondents using specific agents to treat signs and symptoms (S & S), first and second rankings

Agent	Resp: access	First ranking S & S	First ranking % of resp	Second ranking S & S	Second ranking % of resp
CUS	n=98	Scarring	65%	Pain	36%
PUS	n=98	Pain	63%	H/B	57%
CSWD	n=83	Pain	28%	Spasm	11%
PSWD	n=96	H/B	78%	Pain	69%
LASER	n=32	Pain	69%	Scarring	44%

Key: S & S - signs and symptoms; resp - respondents; H/B - haematoma and bruising

This table shows that this group of respondents considered pain to be a strong indication for the use of all forms of electrophysical treatment considered, as it ranked either first or second with respect to frequency of usage irrespective of the form of the agent.

Table 26 shows that ultrasound is predominantly reported to be in use by this group to treat collagen based tissues whereas shortwave diathermy is used for muscle and bursal lesions; laser is reported to be in use for both.

Table 26. A comparison of the % of respondents using specific agents to treat closed lesions, first and second rankings

Agent	Resp: access	First ranking closed lesions	% of resp	Second ranking closed lesions	% resp
CUS	n=98	Ligament tears	45%	Tendon lesions	40%
PUS	n=98	Ligament tears	79%	Tendon lesions	69%
CSWD	n=83	Bursitis	6%	Muscle lesions	5%
PSWD	n=96	Muscle lesions	65%	Bursitis	50%
LASER	n=32	Ligament tears	56%	Muscle lesions	53%

Key: resp - respondents

Open wounds were less frequently treated with any of the agents (table 27).

Table 27. A comparison of the % of respondents using specific agents to treat open lesions, first and second rankings

Agent	Resp: access	First ranking open lesions	% of resp	Second ranking open lesions	% resp
CUS	n=98	Traumatic wounds	6%	Surgical wounds	3%
PUS	n=98	Traumatic wounds	19%	Surgical wounds	17%
CSWD	n=83	All factors	0%		
PSWD	n=96	Traumatic wounds	34%	Surgical wounds	24%
LASER	n=32	Pressure sores	28%	Ulcers	25%

Key: resp - respondents

However, ultrasound and pulsed shortwave diathermy were most frequently used to treat traumatic and surgical wounds whereas laser was used to a similar degree to manage all four lesions listed (see table 24). These last three tables again highlight the point that pulsed agents are reported to be in greater use in clinical practice in England than their continuous counterparts.

5. Electrophysical agents as adjunct therapy: All but two respondents (n=96) provided information which expressed their beliefs about the need to augment the electrophysical management of soft tissue lesions with other forms of physiotherapy treatment.

Ninety eight percent of responses agreed or strongly agreed with the statement 'US, SWD or laser should be augmented by other forms of treatment such as advice, exercise or other physical procedures'. However, 24% of the respondents indicated that such a view depended on the specific condition being treated and consequently agreed or strongly agreed with a statement which indicated that these agents could be effective when used alone for some conditions.

Those who believed that certain conditions could be satisfactorily treated with US, SWD or laser alone were asked to list the soft tissue lesions they had found to respond in a satisfactory manner. Twenty three percent of respondents listed one or more condition, providing a total of 49 examples. These fell into the categories of signs and symptoms, closed and open lesions.

Signs and symptoms: Haematomas (s=5), oedema (s=2), pain (s=2) and scarring (s=1) were listed as signs or symptoms which respondents believed to respond well to electrophysical treatment only.

Closed lesions: A variety of closed lesions were identified by the respondents as responding satisfactorily to either US, SWD or laser alone. These were tendon lesions (s=11), ligament tears (s=6), bursitis (s=6), plantar fascitis (s=2) and muscle tears (s=2). The following closed conditions were mentioned once as benefiting from the use of these agents: calcaneal spurs, tendovaginitis, cystocele, temporo-mandibular disfunction and prolapsed intervertebral disc lesions. Three respondents noted that 'mixed' lesions often responded well to electrotherapy alone, though they did not specify any further details.

Open lesions: Surgical wounds (s=2), ulcers (s=1) and open wound (s=1) were reported to respond to treatment with US, SWD or laser alone.

6. Electrophysical treatments in combination: Pilot work suggested that therapists frequently combined electrophysical agents within a single treatment or sequenced agents within a course of treatment; this was confirmed by the respondents to the questionnaire who reported both practices. Thirty eight respondents agreed with the statement 'sometimes it is useful to use some combination of US, SWD or laser in one treatment session'. These respondents were asked to list the combinations that they used and found effective; 53 responses were provided.

The most popular combination was ultrasound and shortwave diathermy (s=38); this was followed by shortwave diathermy and laser (s=9) and ultrasound and laser (s=6). A more detailed break down of the combinations reported are listed in table 28.

Table 28. Combinations of US, SWD and laser reported to be effective when used in single treatment sessions (n=38)

AGENT COMBINATIONS	NUMBER OF STATEMENTS
US + PSWD	21
SWD + US	13
SWD + LASER	8
US + LASER	4
PUS + PSWD	2
PUS + LASER	2
CUS + SWD	1
PSWD + LASER	1
CUS + PSWD	1
	total = 53

A number of respondents volunteered rationales for their selected combinations. These usually centred around the need to treat two types of tissue or symptoms at the same time. Three respondents stated that a localised treatment such as ultrasound or laser might be given to a specific problem such as a ligament tear whilst a more general treatment such as pulsed shortwave diathermy should be given to the surrounding area which might include further damage. One respondent suggested that US should be given to reduce adhesions and SWD to reduce pain and swelling and a final respondent stated that use was made of two agents when treating a single area, which include different tissue structures such as a joint injury involving ligament damage.

In addition, 86 respondents reported using a combination of US, SWD or laser <u>during a single course of treatment</u> on some occasions. Such usage was sequential in nature.

7. The interchangeable nature of agents: Respondents had clear views about the similarities and differences between ultrasound and shortwave diathermy and subsequently whether they were interchangeable or not. Their responses, however, suggested some confusion about the use and effects of laser. A number of respondents volunteered the information that they had little understanding of the effects of laser.

As five respondents omitted this section of the questionnaire, 93 sets of results were examined.

US and SWD: Seventy one respondents stated that they believed that ultrasound and shortwave diathermy produced different effects when used in clinical practice, whilst 15 subjects stated that the effects were similar. Of these 15 subjects, nine believed that US and SWD were therefore interchangeable. Seventy two respondents took the view that the two agents were not interchangeable, including one who believed that the effects of the two agents were similar. Seven respondents stated that they were not certain whether the effects of the two were different, and 12 stated that they were uncertain whether the agents were interchangeable.

US and laser: Twenty one respondents reported that US and laser were different in their clinical effects, whilst 27 believed that they were similar. Forty seven respondents stated that they were uncertain whether these two agent were different. Twenty three respondents felt that, owing to their similar effects, laser and ultrasound were interchangeable. Nineteen respondents disagreed, reporting that the agents were not interchangeable; 52 reported being uncertain whether the agents could be interchanged.

SWD and laser: Forty three respondents stated that laser and shortwave diathermy produced different clinical effects while only seven reported a contrary view. Forty four respondents were uncertain whether there was a difference between these two agents. One respondent only believed that SWD and laser were interchangeable while 37 believed them not to be. The remainder again reported that they were uncertain (n=45).

Thus 76% of respondents reported differences in clinical effects between US and SWD, 46% reported differences between SWD and laser and 23% reported differences between US and laser. Only 7% reported being uncertain with regard to US and SWD, whereas almost half (47% and 51%) reported uncertainty with regard to SWD and laser, and US and laser respectively.

Those respondents who believed that any of these agent were interchangeable were asked to list the factors which would influence their choice when selecting between agents. Twenty seven respondents provided information in 84 statements, which were categorized according to their content. Table 29 lists these categories in rank order and shows that the size of the lesion, the local pathology and the location of the lesion accounted for 41 statements or 49% of the total.

Table 29. Factors affecting choice of electrophysical agents (n=27)

FACTORS	NUMBER OF STATEMENTS
Size of lesion	19
Pathology	13
Location of lesion	8
Acute/chronic lesion	6
Depth of lesion	6
Increased/ decreased sensitivity	5
Equipment available	5
Time available	4
Presence of infection	3
Prior experience	3
Aims of treatment	3
Muscle spasm	2
Preference (Therapist)	2
Swelling	1
Preference (Patient)	1
Medication	1
Open/closed wound	1
Ease of application	1
	Total = 84

8. Placebo effects: Eighty five respondents reported believing that placebo effects arose from the use of electrophysical agents; 8 reported being uncertain and 2 that such effects did not occur. Four respondents did not reply to this section of the questionnaire, the total number of responses therefore being 94.

Those who thought it likely that placebo effects would arise from the use of electrotherapy (n=83) also reported on the occurrence of placebo effects with other forms of physiotherapy treatments and through the interaction between patient and therapist. Fifty eight respondents agreed or strongly agreed with the statement 'placebo effects arise from most other therapy techniques' and 77 respondents agreed or strongly agreed with the statement 'placebo effects arise from interaction with the therapist'. Thus electrophysical agents (n=83) were believed to result in greater placebo effects than interaction with the therapist (n=77) or other therapeutic interventions (n=58).

Those respondents believing that electrophysical agents resulted in placebo effects were asked to rank order ultrasound, shortwave diathermy and laser according to the level of placebo they thought each was likely to induce. Laser was believed to induce greatest placebo effects, 53 respondents ranking it first. Ultrasound and shortwave diathermy ranked almost equally, SWD being ranked first by 35 respondents and US first by 34 respondents. Thirteen respondents ranked all three agents equally, nine ranked US and laser equally and one SWD and laser equally.

9. Sources of information: Respondents provided information about the tuition they had received to prepare them for the use of each agent under question. All respondents completed this section (n=98).

Undergraduate tuition: Over 90% of all respondent reported that they had received formal undergraduate training in the use of both continuous (91%) and pulsed ultrasound (92%) and continuous shortwave diathermy (95%). Less than half of the respondents (47%) reported receiving training in the use of pulsed shortwave diathermy and only 9% training in the use of laser.

Table 30 shows the training received by the different clinical grades of respondents.

Table 30. Number and clinical grade of respondents receiving undergraduate education in ultrasound, shortwave diathermy and laser

	CUS	PUS	CSWD	PSWD	LASER
Staff (n=24)	22	22	22	18	6
Senior II (n=37)	34	34	36	22	1
Senior I (n=25)	22	23	24	6	2
Super (n=12)	12	12	12	1	0

This information may provide some indication of the changes in undergraduate training which have taken place in recent years. For example, the majority of those reporting training in the use of laser and pulsed SWD were the junior staff and were more likely, therefore, to have been trained recently.

Staff grade therapists had received the most extensive undergraduate educational input with respect to US, SWD and laser; 92% had been trained in the use of CUS, PUS and CSWD and 75% in the use of PSWD. Six of the 24 staff therapists had been trained in the use of laser, suggesting that though the teaching of laser may be increasing, it is still not frequently considered at the undergraduate level. When compared with one another, senior II and senior I therapists reported a similar level of training in CUS, PUS and CSWD (between 88% and 97%), a substantial increase in training in PSWD from 24% (senior II respondents) to 59% (senior I respondents) and a very slight increase in training in laser. No superintendent grade therapists reported having been trained in the use of laser and only one had received training in the use of PSWD; they had all, however, received training in the use of PUS, CUS and CSWD.

Post-graduate tuition: Thirty six respondent reported attending courses, of half a day's duration or longer, on both pulsed and continuous ultrasound; two respondents attended such courses on pulsed US only.

Eleven respondents had attended courses about continuous shortwave diathermy and 29 about pulsed SWD. Of the two respondents who reported not having training at the undergraduate level in CSWD, one had completed a postgraduate course, though both made use of the agent in clinical practice. Of the 49 respondents who had not received formal undergraduate training in the use of PSWD, 21 had completed postgraduate courses. All but one of the remaining 28 respondents made use of PSWD in clinical practice despite a reported lack of formal undergraduate training or substantive postgraduate input.

Thirty respondents stated that they had attended postgraduate courses about laser therapy. Of those with current access to laser equipment (n=32), two reported receiving undergraduate training in its use and 14 reported attending postgraduate courses; 16 had, therefore, no formal training in the use of this agent. Of these, 13 respondents reported making use of the laser in the treatment of some form of soft tissue lesions.

10. Sources of information: Reporting on sources of information found to be most useful in informing their practice, the following options were rank ordered by the respondents; discussion with colleagues, personal experience, literature, courses (postgraduate) (table 31).

Table 31. Sources of information ranked as most useful by respondents according to their perceived value in informing practice (n=98)

SOURCE OF INFORMATION	NUMBER OF RESPONDENTS
Literature	34
Discussion with colleagues	30
Personal experience	26
Courses	18
	total = 108

Table 31 shows the ranking of these sources, each respondent having ranked the named source as the most useful. A number of respondents rated a number of sources as equally useful, resulting in a total which is greater than the number of respondents. All respondents had access to the first three sources of information whereas not all respondents has received formal tuition in all subjects at either the under- or post-graduate level. This factor may partially account for the low ranking given to the latter, with 61 respondents ranking courses in fourth place. However, 21 of these had attended courses of half a day or longer on specific agents. It is not known whether the remaining respondents (n=41) had attended other, shorter courses or in-service training programmes or whether they completely lacked training in the use of these agents. Of the 18 respondents who rated courses as the most useful source of information, four reported not having attended any postgraduate courses of half a day or more, suggesting that shorter courses and in-service training may be a useful source of information about the use of electrophysical agents to some therapists.

Section II. Chapter 6.

USAGE OF ELECTROPHYSICAL AGENTS: DISCUSSION

Ultrasound, shortwave diathermy and laser were all reported by the physiotherapists taking part in this study to be used to treat a wide variety of soft tissue lesions. The most commonly used forms were those which effected change through the use of the nonthermal effects claimed for each. Four main points were highlighted; these were (1) the varied and changing patterns of possession and usage of agents over time and across geographical boundaries; (2) the discrepancies between reported behaviour and reported opinions with respect to usage; (3) the strongly held beliefs by physiotherapists about the placebo effects of these agents and (4) the scant educational backgrounds reported by these respondents. Each of these points will be considered in turn.

Patterns of usage: Patterns of usage are inevitably affected by both the availability of equipment and the treatment selection policies of the individual.

Current availability in England may be compared with that reported in other studies in Britain and abroad, both recently and in the past. Both the literature and discussion with colleagues from abroad suggest that usage may differ on a global level; McMeekan (1994), in a personal communication, drew attention to the differences in the clinical practice of practitioners originating from North America and Britain, with British therapists showing greater interest in nonthermal agents. She noted that Australian practice is currently split between the two approaches, regional practice varying according to the local population and their geographical origins.

In this study ultrasound was found to be available in all departments accessed, closely reflecting previous reports of availability in Britain (Ide and Partridge, 1986; 1989), the United States of America (Robinson and Snyder-Mackler, 1988) and Australia (Lindsey et al, 1990). This contrasts with earlier studies, such as that of the Canadian Department of Health and Welfare (1980a; b) and Venton-Gough (1962), which reported that ultrasound was less generally available and the greater prevalence of standard thermal agents such as shortwave and microwave diathermy. This earlier pattern is corroborated by evidence in textbooks designed to serve the needs of physiotherapists in the 1960s and 1970s, which again suggests that greater emphasis was then placed on thermal agents (Licht, 1958, 1965; Scott, 1969).

Continuous shortwave diathermy appears to be experiencing a decline in popularity in both England and Australia; though similar levels of availability were reported in this study and that of Lindsey et al (1990), there appears to be a gradual decline in availability in both countries compared with earlier studies which suggested that almost all physical therapy departments held such equipment (Venton-Gough in 1962; DWH, 1980b). Though fewer studies report the availability of pulsed shortwave diathermy, the evidence available suggests that this agent is much more commonly available in England than in other countries. Almost all respondents in this study reported access to it, whereas Lindsey et al (1990) reported that it was available to less than a quarter of their sample in Australia.

Laser, in contrast, is a new agent and appears to be gradually gaining ground in a number of countries (Baxter et al, 1991; Lindsey et al, 1990; McMeekan and Stillman, 1993). The present study suggests that it may be more widely available in England than elsewhere; laser was available to twice as many respondents in the present study as to those reported by Lindsey et al (1990). However, the number having laser is still small, with about a third of the total sample in this study reporting access to it.

Few studies have reported reasons for physiotherapists choosing to hold equipment, though those having laser have stated that it is a convenient source of energy, local application is easy, patients like and even demanded it and that it is seen to be effective (McMeekan and Stillman, 1993). In contrast, a number of reasons have been suggested, both by respondents in this study and in other reports, for physiotherapy departments <u>not</u> holding certain types of equipment. Both work in the early stages of this study and the studies of Lindsey et al (1990) and McMeekan and Stillman (1993) report that purchase may be inhibited by cost, limited knowledge of effects, efficacy, dosages, the availability of other agents and safety concerns. In addition manufacturer's sales policies can have a major effect on purchases. Both Baxter et al (1991) and McMeekan and Stillman (1993) report that purchases of laser equipment are strongly influenced or even initiated through sales advertising, manufacturer's workshops and loan systems.

Patterns of usage are not only governed by availability but also by the choices made by physiotherapists and the conditions referred to them. The sample of physiotherapists in this study reported extensive use of electrophysical agents for the treatment of soft tissue lesions and indicated that ultrasound, shortwave diathermy and laser are generally used for the same conditions.

Pulsed, low energy treatments are reported to be used more frequently in Britain than their continuous counterparts, despite the limited knowledge available about the efficacy of these forms of energy. As has been shown in Section I (chapters 5 and 6), there is currently scant laboratory or clinical evidence of benefits from the use of pulsed shortwave diathermy and limited evidence of the clinical efficacy of ultrasound or laser.

It was not possible to perform any statistical tests to examine whether there were significant differences between numbers using each agent; this was for two reasons. Firstly, not all respondents had every agent available to them, which resulted in different sample sizes, and secondly, multiple responses were received as respondents often used more than one agent for a single condition. Many differences and similarities are, however, of such an order as to be self evident.

Both ultrasound and pulsed shortwave diathermy were reported to be popular choices of treatment, with three quarters of the respondents using ultrasound frequently (defined here as on one day a week or more), levels which reflect the reports of Robinson and Snyder-Mackler (1988) and Lindsey et al (1990). Pulsed shortwave diathermy was reported to be an equally popular choice of treatment in this study, though the continuous form was not, only 16% respondents reporting regular usage. This contrasts with reported use in Australia where continuous shortwave diathermy is used more often than pulsed (Lindsey et al, 1990). Laser is currently reported to be less often used in England than either ultrasound or pulsed shortwave diathermy, though the primary reason for this may be lack of availability; half of the respondents in the current study, as in the Australian study, with access to laser reported using it frequently. Thus, though usage of laser in England is less than for both pulsed shortwave diathermy and ultrasound, it is considerably more than for continuous shortwave diathermy.

Usage was also examined with respect to the conditions treated and respondents in this study reported that <u>all</u> conditions were treated with <u>all</u> forms of energy. All the signs and symptoms listed in the questionnaire were reported to be treated with each agent, though pulsed, low energy agents were most extensively indicated. For example, over 60% of respondents with access to each piece of equipment reported using pulsed ultrasound, pulsed shortwave diathermy and laser to treat pain, suggesting that therapists behave as though agents are interchangeable in clinical practice.

Reports of the treatment of open wounds were much less frequent. Again reports of the use of nonthermal agents predominated with pulsed shortwave diathermy and laser being most popular. Though the literature (Section I, chapter 6) indicates that ultrasound and laser may be effective treatments for ulcers, and that ultrasound and pulsed shortwave diathermy can be used effectively to aid the resolution of acute lesions, these benefits do not appear to be being transferred into clinical practice <u>within the out-patient sector</u>. The reasons for this may include the use of alternative methods of treatment such as pressure bandaging, specialist wound dressings, the use of topical and systemic drugs and hyperbaric oxygen therapy for the care of ulcers and the possibility that open lesions of all types may be treated by physiotherapists in alternative locations such as specialist vascular and skin clinics, wards or community based situations. [Callam et al (1985) reported that 16% of the ulcers patients they accessed were being treated by physiotherapists, with over 80% of the total number being treated in the community].

Usage of electrophysical agents in isolation from other forms of therapy is rare in clinical practice, a point highlighted by this study. However, in addition this study revealed that over one third of respondents reported combining one electrophysical agent with another in a single treatment. All possible combinations of the three agents being examined were used by the respondents, though ultrasound and pulsed shortwave diathermy were the most frequently sited. The literature provides no clear evidence to suggest that such a practice is useful though some possible benefits may be postulated. For example, ultrasound is thought to be primarily effective at the level of the cell membrane whilst laser is believed to affect the respiratory chain mechanism via the mitochondria; two sites of stimulation may result in an enhanced tissue repair response. Differences in tissue structure may be a factor; ultrasound and shortwave diathermy are absorbed preferentially by collagen and muscle respectively and this difference might again lead to more effective treatment. It is also possible that one form of electrophysical treatment could be synergistic with respect to another, as is the case is the use of certain drugs. Again, the conduct of further investigations may reveal that electrophysical agents are selective in the cells they affect; for example, evidence to date indicates that ultrasound may stimulate platelet activity and laser keratinocyte proliferation (Williams, 1974; Steinlechner and Dyson, 1993). However, further studies are needed to show that each agent is not, in fact, able to perform both functions.

On the other hand, it is also possible that the combined use of electrophysical therapies may be detrimental to tissue repair. Both Dyson (1990) and Karu (1988) have suggested that overdosing with single agents can have detrimental effects on tissue repair, an effect described in

Ohshiro's diagrammatic representation of the Arndt-Schultz law (Ohshiro and Calderhead, 1988). Though this effect is more likely to occur with raised energy intensities and/or sound pressure it is also possible that longer times, as when using two agents in sequence, may be unnecessary or detrimental. In addition, the use of thermal and non-thermal agents together may have a detrimental effect on repair; heat can increase the inflammatory response of tissue whereas most nonthermal agents are believed to speed up the process of inflammation. Together these two effects may inhibit repair rather than optimize it. Some manufacturers now produce equipment which allows agents to be applied simultaneously rather than sequentially; under these circumstances it is possible that certain effects, such as thermal changes, could summate.

A number of reasons were spontaneously supplied by respondents for their use of more than one agent. These focused, firstly, on the need to treat both locally, for example using either laser or ultrasound, and more generally perhaps using pulsed shortwave diathermy and, secondly, on a belief that different agents were beneficial with respect to different tissue types (for example, ultrasound might reduce adhesions, possible through its perceived mechanical, micromassage action) and symptoms (for example, pulsed shortwave diathermy could reduce pain and swelling).

Currently there is no scientific or clinical evidence to support or refute this clinical practice; studies are therefore required to examine the effects of the most common combinations at both cell and, subsequently, clinical levels.

Reported behaviour versus reported opinions: As a number of respondents at the pilot stage had suggested that many agents were similar to one another and therefore frequently interchangeable, it was decided to examine perceived similarities and differences and compare these to the types of conditions respondents reported treating.

Almost three quarters of the respondents in the main study reported believing that ultrasound and shortwave diathermy produced different clinical effects, a half that shortwave diathermy and laser were not the same, and a quarter that ultrasound and laser were different, results which are not borne out by their reported usage. An examination of the tables of results in Section II, chapter 5 (tables 9 to 22) shows that all agents are used to treat all signs, symptoms and closed lesions listed and most agents used to treat all open lesions listed. The discrepancy between these two sets of results may be due to respondents feeling diffident about suggesting that agents were regarded as similar in practice, though there was no indication of this in either the preliminary work or when piloting the questionnaire itself. Alternatively, respondents may not have been aware of the discrepancies between what they report believing and report doing.

The review of the physiological and clinical effects of ultrasound, shortwave diathermy and laser presented in Section I of this thesis suggests that many of their effects appear to be similar, though their physical behaviour (such as penetration depth and absorption characteristics) may vary. However, the developing and piloting of this questionnaire highlighted the problems many therapists have in accessing and understanding the known nature, behaviour and biological effects of all three agents, and it may be that these difficulties have led to the discrepancies shown here.

Placebo effects: Simmonds and Kumar (1994) suggest that placebo effects are initiated through treatment, the attendance of the patient at a clinic and the presence and care of a therapist. In addition, it has been demonstrated that the beliefs and expectancies of both clinicians and patients can affect the placebo response (Peat, 1981; Bootzin, 1985; Gracely et al, 1985). In this study, treatment in the form of electrotherapy was clearly seen as likely to give rise to these effects, with laser believed to mediate the greatest placebo related changes. This view reflects work in the field of ultrasound (El Hag et al, 1985; Hashish et al, 1986, 1988; Lundeberg et al, 1988) and laser (Klein and Eek, 1990; Vasseljen et al, 1992; Simmonds and Kumar, 1994) which has shown that placebo effects do arise with the use of these agents, though no quantification of this effect has taken place; no studies have been identified which consider this aspect with respect to shortwave diathermy.

Therapists' beliefs about the placebo effects mediated by the therapist themselves and 'other' physiotherapy treatments used were compared to that of electrotherapy. Interaction with the clinician was believed to give rise to less effect than the use of the agents themselves, whilst only half of the respondents reported believing that other therapeutic techniques produced placebo mediated changes. These last two beliefs are surprising. Peat, in 1981, suggested that the therapist may be the most powerful placebo of all, owing to the development of quality relationships with the patient during one-to-one contact over prolonged periods of time. Similarly, though the placebo effects arising from general rehabilitation processes have received scant attention, studies such as those by Beecher (1955), suggest that placebo effects due to a variety of interventions can range from 15-58%. It seems unlikely therefore that physiotherapy treatments other than those involving electrophysical agents are void of this effect.

Mayer and Price (1989) note that the placebo effect is extinguished with time and this may be a mechanism underpinning the observation, reported at the early stages of the study and confirmed by later respondents, that clinical benefits arising from changing from one type of electrotherapy to another during a course of treatment as the perceived efficacy of the first declines. This suggestion is supported by reports derived early in the development of this study which suggested that <u>any</u> change was perceived by some to be clinically effective.

This study accessed only the <u>beliefs</u> of therapists about placebo effects; it is clear that much work is needed to examine and quantify this parameter with respect to the therapies. Some studies which incorporate examination of these effects due to electrophysical agents have suggested that there is no difference in efficacy between the those receiving sham treatment and those having active treatment (Lundeberg et al, 1987; Hashish et al, 1986, 1988; Grant et al, 1989). Developmental work for this study suggested that a number of therapists believe that electrotherapy is primarily effective through its placebo effects and that some specifically use it for these benefits. Such use of treatments is questioned by Simmonds and Kumar (1994) who, whilst agreeing that placebo effects can be useful, doubt whether therapists should employ treatments that primarily rely on this mechanism; they suggest that clinicians and manufacturers of equipment should constitute part of the solution to the current health care financial crisis rather than add to the problem by the purchase of expensive, placebo mediating equipment.

Educational profiles: Training in the safe and effective use of electrophysical agents has come under considerable scrutiny in recent years by the Chartered Society of Physiotherapy. This study, which looks at the profiles of physiotherapists of different grades suggests that undergraduate education has gradually changed over the years and that junior clinicians, who are likely to have completed training most recently, are most likely to have received training with respect to all three agents in question.

In 1987 ter Haar et al reported that two thirds of their NHS sample had been trained in the use of ultrasound whereas almost all respondents in the present study reported receiving such training. A steady increase in education about pulsed shortwave diathermy is reported with greater numbers of staff at more junior levels having received tuition. Few respondents, however, had received undergraduate education in the use of laser, and those who had were almost all junior staff. However, even the levels reported in this study are an increase on those reported by Baxter et al in 1991, who found that no respondents in Northern Ireland had received formal undergraduate training in the use of the agent. In this study approximately one third of respondents reported that low undergraduate input was augmented by attendance at postgraduate courses.

These results, however, suggest that a number of clinicians appear to be using electrotherapy equipment to treat patients without adequate, recognised tuition. For example, almost one third of the respondents reported using pulsed shortwave diathermy and 13 using laser whilst reporting no formal education of any kind. This contravenes the recommendations of the Electrotherapy Safety Working Party set up by the Chartered Society of Physiotherapy (Docker et al, 1992; Low et al, 1991; Safety of Electrotherapy Equipment Working Party, 1990) and could lead to professional and legal problems.

Not all information used by physiotherapists is provided through formal tuition; less formal sources were used and valued, with two thirds of the respondents indicating that either literature or discussion with colleagues was their most valuable source; both results reflect the work of other researchers in Britain and abroad (Robinson and Snyder Mackler, 1988; Baxter et al, 1991; McMeekan and Stillman, 1993). Early developmental work in this study suggested that books, journals and manufacturers' literature provided much information, the latter being the most commonly used. Personal experience was also highly valued by over half of the respondents, again reflecting the work of Baxter el al (1991). Whilst personal experience must remain a valuable source of information for all clinicians, it is of some concern that it is ranked so highly by so many, especially in those lacking the basic educational support.

Few respondents ranked attendance at courses as the most useful source of information. However, whilst all respondents are likely to have access to the other sources of information considered not all may have been able to attend postgraduate courses. This factor may partially account for the low ranking given to the latter, with over two thirds ranking it last. However, the result reflects the work of Robinson and Snyder-Mackler (1987), Baxter et al (1991) and McMeekan and Stillman (1993) who all report that continuing education seminars, graduate education courses and conferences were the least used sources of information. Finally it should be noted that a number of respondents, who rated courses most highly, reported not having attended any postgraduate courses as defined in this study. This may suggest that shorter courses of less than half a day and in-service training may be a useful source of information.

Conclusion: Ultrasound, shortwave diathermy and laser are commonly used agents in the management of soft tissue lesions; the reports provided in this study suggest that they are commonly used for the same conditions, despite many respondents reporting the belief that they differ with respect to their clinical benefits. This discrepancy may be a direct result of the limited educational background reported by many of the respondents compounded by the fact that knowledge about the physiological and clinical effects and efficacy of each of these agents is patchy and, particularly with respect to pulsed shortwave diathermy, very limited.

Despite these problems many continue to use electrophysical agents in practice for a wide variety of conditions, selecting between the different forms available. Problem solving under conditions of uncertainty is a complex task but common in the medical professions (Balla et al, 1989). The following section will examine the ways in which experienced physiotherapists evaluate soft tissue lesions and develop a plan of treatment.

SECTION III

CLINICAL PROBLEM SOLVING:

SELECTION OF ELECTROPHYSICAL TREATMENTS

SECTION III. PREFACE

Section II of this thesis has examined the current usage of ultrasound, shortwave diathermy and laser by physiotherapists in England and has identified a number of factors which can contribute to their selection of treatment. The Section starts to examine in greater detail the problem solving processes employed by experienced clinicians as they select treatment for patients with soft tissue lesions. The purpose of this study is to begin to identify the processes and factors which contribute to treatment selection and thus affect the final outcome of physiotherapy intervention.

This section of the thesis consists of four chapters; the first reviews the theoretical principles which underpin the study of human reasoning and decision making and reviews a variety of studies which have examined problem solving in practice, both general and clinical. The second chapter evaluates the research methods available to examine clinical problem solving and identifies that which is most suitable for the current investigation.

Chapter three of this Section describes the development of the research tools used in this study and presents the results of the investigation, whilst the last chapter discusses the results of this study in the light of the theoretical principles outlined in the first chapter.

Section III. Chapter 1.

PROBLEM SOLVING

Clinicians have long held medical decision making in high regard, believing it to be an integral part of their expertise and professionalism. There is, however, an increasing concern among both researchers and some practitioners about the reliability of the processes used and the quality of the decisions made. Dowie and Elstein (1988) suggest that two questions need to be asked; 'how do clinicians make judgements?' and 'how well do clinicians make judgements?'. The answers to these questions may be used to inform the practice of clinicians and the education of students.

Balla et al (1989) emphasise that clinicians work within an environment which is characterised by uncertainty. Work by experimental psychologists indicates that human decision makers are not good at information integration (Dawes, 1980) and that greatest difficulty arises when information comes from a number of dimensions and is not immediately compatible (Shepard, 1964), or when information about one or more dimension is incomplete (Slovic and MacPhillamy, 1974). Both conditions apply to medical problem solving.

The problems associated with decision making under conditions of uncertainty have been demonstrated in a variety of studies; examples include work which evaluates the competence of problem solving in predicting deaths, student success rates, identifying factors affecting student removal from education, the severity of disease, the occurrence of disease and the quality of journal articles (Dawes, 1971; Einhort, 1972; de Dombal and colleagues, 1972, 1974, 1984; Mahoney, 1977; Lichtenstein et al, 1978; Arkes and Harkness, 1983). Accurate judgements, when it was possible to verify these, were low, averaging around 50% even when the task was performed by experts. In addition some work suggests that clinicians use both heuristic rules and intuitive methods to make choices between differing strategies in diagnosis and management. Thus Balla et al (1989) comment 'it comes as no surprise that they are not always successful in their choices and improvements should be looked for and welcomed'.

Accuracy is improved when a problem solving aid is used but is rarely 100%; for example, an assisted system to assess neuroticism using the Minnestota Multiphase Personality Inventory (Goldberg, 1968), provided accuracy levels of 70%. This is significantly better than that of the clinical judges whose accuracy is frequently in the region of 40 - 50% (de Dombal, 1984). Similarly de Dombal (1984) reported studies comparing diagnosis of acute abdominal pain with and with out an aid; all studies showed an increase in diagnostic accuracy following practitioner contact with the aid under consideration.

Many forms of assistive device have been developed, including algorithms, decision trees and computer aided systems. Frequently, though not always, they are based upon an examination of the problem solving strategies of experts in the field. There are a number of reasons for this;

Schön (1992) believes that the expert in a field is functioning at the highest level and that information elicited from them about their problem solving strategies should therefore be used as the basis for helping the novice. Goldberg (1970), Forsyth (1984) and Fox (1987), whilst not having such high views of the professional ability of the expert, believe that the integrated problem solving skills of a number of experts provided through an assistive device, results in better and more accurate problem solving.

THE HISTORY OF THE STUDY OF REASONING

Interest in the development of the concepts and process underlying reasoning extends back at least as far as Socrates (469-388 BC), Plato (427-347 BC) and Aristotle (384-323 BC), the last of whom fathered many of the concepts underlying present day Western thought patterns and the structure of formal logic (Burnett, 1963; Medawar, 1969; Harré, 1972). The study of reasoning has developed over the years and encompasses a wide area of philosophical debate, parts of which can only be touched on briefly in this review.

Aristotle's philosophy included the following areas: conceptual representation, the organisation of concepts and the organisation of thought processes (Howes, 1990). He developed his arguments in response to the teachings of the Sophists, who were travelling teachers of his day. The individual citizens of the Greek culture were expected to defend themselves in court, should the need arise, and were thus interested in the understanding of logic and reasoning. Aristotle took issue with the Sophists in that their approach was unashamedly rhetorical; they used information to suit the purpose rather than solely relying on the use of rational, reasoned argument (Aristotle, translated 1959; 1985).

Many western philosophers followed the lead provided by Aristotle, taking up differing aspects of the discussion, including the role of sensory perception, learning, innate knowledge and interpretation; Descartes (1596-1650), Locke (1632-1704), Hume (1711-1776) and, most importantly, Kant (1724-1804) developed philosophies of reasoning, building upon one another's work. At the turn of the nineteenth century a new approach was developed by those termed 'logical positivists'; these included Frege, Russell and Whitehead, whose work is discussed and compared by Russell (1974) and Magee (1987). Russell and Whitehead were mathematicians and this led to a new dimension being added to the debate. 'Symbolic' or 'mathematical' logic was developed which addressed a number of issues that Aristotelian syllogistic logic had found intractable.

During the last century the philosophical approach to reasoning has been augmented by the 'scientific' study of the processes of thinking. This approach, whilst not replacing the philosophical debate of logic and reasoning, has served to clarify the ways in which people reason in practice and has highlighted a number of important issues.

Early scientific work, which aimed to examine thought processes and practical problem solving, occurred mainly in the discipline of psychology and consisted primarily of laboratory based studies; more recently, researchers have turned their attention to the evaluation of reasoning in life situations among a variety of groups and professions (Thomson, 1971). Medical practice has increasingly become the subject of evaluation over the last two decades, work initially focusing on medical practitioners and on the diagnostic process (Dowie and Elstein, 1988). Later studies have expanded the scope of the decisions examined and have evaluated the decision making processes amongst other medical staff, including nurses, midwives and health visitors (Benner and Tanner, 1987; Westfall et al, 1989; Orme and Maggs, 1993), occupational therapists (Mattingly, 1991; Fleming, 1991) and physiotherapists (Payton, 1985; Dennis and May, 1987; Thomas-Edding, 1987; Higgs, 1991).

THE THEORY AND PRACTICE OF REASONING

The study of thought and reasoning falls into two areas; firstly, that of the theory underlying the process and, secondly, the actual inferences and resultant action. Flew (1976) likens these two parts to the theory underlying the playing of a game and the actual playing itself. The theoretician, or logician, must know the object of the game and the rules of the game, and must examine the game in this light; the practitioner must put the game into action, whilst remembering and abiding by the underlying aims and principles. The study of logic forms the basis of the first part of this duo, whilst the study of problem solving addresses the applied aspects.

Theoretical Principles - Logic:

Logic has been defined as 'the study of the structure and principles of reasoning or of sound argument' (Flew, 1976). Reasoning, which looks at the validity of argument and the truth of propositions, may be divided into deductive and inductive reasoning, both of which have their origin in Greek philosophical traditions. More recently, hypothetico-deductive reasoning has been identified as a subdivision of these categories.

Deductive reasoning:

Deductive reasoning is defined as 'a valid argument in which it is impossible to assert the premises and to deny the conclusion without thereby contradicting oneself' (Flew, 1975). The aim of a deductive argument is to induce belief in the conclusions by force of reason; such arguments are termed logically valid. Such reasoning involves the derivation of information from prior statements and is the study of argument. A number of premises are considered and a conclusion derived.

The notion of an appeal to reason to determine validity has led to considerable debate by philosophers such as Aristotle, Bacon, Hume and Popper (Aristotle, 1985; Popper, 1980; Magee, 1987). A careful distinction must be drawn between an inference which may be regarded as reasonable and one whose acceptance is compelled by reason. The first is inadequate as a base for acceptance of the argument as logically valid. In order for an argument to be accepted as logically valid it must be possible to demonstrate that it is irrational to accept the premise but not the conclusion or vice versa (Aristotle, translated 1959; 1985).

A deductive argument frequently, but not always, takes the form of a syllogism (Flew, 1975; Baron, 1988). Aristotle (cited by Flew, 1975) defined a syllogism as 'a discourse in which, certain things being stated, something other than that what is stated follows of necessity from their being so'. A syllogism must be valid to be of any worth. Thus if the premises are assumed to be true, the conclusion must be true if the argument used is itself valid. When a syllogism is valid the conclusion must follow from the premises. The following example demonstrates a typical deductive argument in the syllogistic form:

> All men are mortal
> No Gods are mortal
> Therefore no men are Gods   Aristotle (translated 1959)

However, it is possible for the conclusion to be untrue and yet the syllogism still to be valid; this normally results when one or more of the premises is untrue or there is ambiguity present. An example of each follows:

1. All cats have five legs
   Bugs Pussy is my cat
   Bugs Pussy has five legs

(Chalmers, 1982)

2. Nothing is better than eternal happiness
   A ham sandwich is better than nothing
   Therefore a ham sandwich is better than eternal happiness.

(Nickerson, 1986)

Determining the validity of such arguments is dependent on carefully argued reason and is often more difficult than is immediately apparent. The introduction of words such as 'if', 'and ', 'or', 'some' and 'all' can increase the complexity of the deduction considerably.

Propositional logic includes the terms 'if', 'and', 'or' and 'not'. An example illustrates the form;

If there is an F on the paper, there is an L
If there is not an F there is a V.
Therefore, there is an F or there is a V.

Categorical logic includes the terms 'all', 'some', 'none', 'not' and 'no'. Two examples are as follows;

I. All A's are B's
All B's are C's
Therefore all A's are C's.

II. Some A's are B's
No B's are C's
Therefore some A's are not C's

Many other combinations and variations are discussed in the literature on logic; both propositional and categorical logic may be combined and the wordings refined and redefined. Examination of such arguments rapidly highlights the complexity of the reasoning required and the ease with which incorrect conclusions can be reached (Henle, 1962; Johnson-Laird and Bara, 1984).

Deductive reasoning may be used in practical problem solving and will be discussed further in the following section. Life situations encountered in clinical practice may give rise to complex syllogisms due to the need to accommodate variety and uncertainty and will thus be subject to misinterpretation and error.

Inductive reasoning:

Inductive reasoning has been defined as 'any rational process where, from premises about some things of a certain kind, a conclusion is drawn about some or all of the remaining things of that kind' (Lacey, 1976). Flew (1976) notes that it is a form of reasoning by which a general law or principle is inferred from observed particular instances. An argument may be described as inductive if it claims to draw a conclusion from premises in a single step; the term covers all arguments in which the truth of the premise(s), whilst not entailing the truth of the conclusions, or the conclusions themselves, 'nevertheless purports to constitute good reason for accepting (the conclusions)' (Flew, 1975).

Many inductivists believe that a hypothesis may be supported directly by evidence; thus, in its simplest form, if A1 is ●, A2 is ● and A3 is ● it follows that all A's are, probably, ●. Inductive reasoning is a form of thought that estimates the probability of a conclusion being true; an argument is inductively strong if it is highly probable that the conclusion follows from the premises. Hawes (1990) states that 'the inductive probability of an argument is that its conclusion is true, given that its premises are true'.

The advantages and the difficulties associated with the inductive method were highlighted by Bacon and later more fully discussed and argued by Hume, Popper and many other philosophers (reviewed by Popper and Eccles, 1977; Magee, 1987). Inductive reasoning does not depend upon the form and wording of the propositions in the same way as deductive reasoning and is thus less susceptible to misinterpretation or invalid deductions. However, many philosophers have highlighted the difficulties associated with imputing general conclusions to specific observations. In particular, Wason and Johnson-Laird (1968) emphasise that inductive inferences go beyond the given data; there are, therefore, no criteria for assessing their validity.

Hypothetico-deductive reasoning:

These problems led to the development of the hypothetico-deductive model, posited originally by Popper and colleagues (Popper and Eccles, 1977;

Popper, 1980) and considered by some to be more appropriate to practical reasoning (Thomson, 1971). In this model it is suggested that 'when all known cases of so-and-so have been found to be such and such, expect and presume that other so-and-so's have been and will be, until and unless you discover some particular reason to revise these expectations' (Flew, 1975). This process fundamentally involves the development and subsequent testing of one or more hypothesis. Groen and Patel (1985) define a hypothesis as 'a verbal statement about a situation that may be either true or false (although one may be uncertain of its truth or falsity in practice)'. Information is collected, hypotheses developed and a decision ultimately made on the basis of the tested hypothesis.

The development of hypotheses early on in the process may be an inductive activity as their generation is inferred from the specific situation; divergent thinking is thus used. These hypotheses then act as a guide to subsequent information searches; this process narrows down the quest and is a form of convergent or deductive thinking.

Practical consequences - problem solving

Reasoning in practice has been termed problem solving by a number of psychologists (Wason and Johnson-Laird, 1968; Thomson, 1971; Baron, 1988). Thomson, in 1971, defined problem solving as 'thinking in action'. Baumann and Dauber (1989) differentiate between problem solving - 'the search for a correct solution to a problem' - and decision making -

'situations in which a choice is made among a number of possible alternatives, often involving trade offs among the values given to different outcomes'. Others, including Jenkins (1985) believe that this distinction is unnecessary and describe problem solving more generally as a problem requiring a solution. In this study the latter view is adopted.

Whilst deductive, inductive and hypothetico-deductive reasoning processes may be incorporated into practical reasoning, other, less objective, elements such as the use of heuristics and intuitive methods may also be employed.

Initial research to examine the process of problem solving involved the use of introspection as the major investigative tool (James, 1890; Titchener, 1912; Binet, 1969). These methods were later regarded as unscientific as both behaviourial psychologists, for example, Judson et al (1956), and 'holistic' or 'mentalist' psychologists, such as those of the Würzburg School and Gestalt tradition, continued to examine the concept.

Behaviourists focused on the correlation between observable stimuli and responses; theirs was considered an objective system (Watson, 1913; 1924; Judson et al, 1956). Problems, however, arose as it became increasingly clear that thought and reasoning processes are not directly observable.

'Mentalist' psychologists believed it was impossible to atomise thought; it was important to examine whole perceptual images. Those of the Würzburg

School emphasised the importance of instruction in the reasoning process; they postulated a 'determining tendency' which guided and controlled the process of thinking. On the other hand, Gestalt psychologists such as Köhler (1917), emphasised the structure of the problem and the process of reorganisation required to facilitate insight into the solution to the problem.

The history of problem solving includes the investigation of animal and human behaviour, and the examination of verbal reports. Early studies with human subjects were mainly based in the laboratory (Maier, 1931; Duncker, 1945; Wertheimer, 1945). The effects of trial and error, practice, prior information and experience in allied fields have been explored; problems allowing practical trial and those demanding hypothetical reasoning have been examined. For example, Maier (1931) examined a problem which allowed the participant to indulge in 'trial and error'; he told his subjects that 'your problem is to tie the ends of those two pieces of string together'. The participant quickly learned that the two pieces, which were suspended from the ceiling, could not be reached from a single standing position. Additional equipment including tables, chairs, additional cord, weights and poles, was provided. Maier (1931) encouraged his subjects to find as many methods as possible to achieve the goal.

Dunkner (1945) examined problem solving in which practical 'trial and error' was not possible; the participants in this study were required to describe their thought processes. The problem posed was one of treating an inoperable stomach tumour with deep X-ray treatment without destroying the surrounding healthy tissue. Later a variety of puzzles, games and mathematical problems were posed in which the subject was again required to outline the steps taken to arrive at the solution (Kilpatrick, 1968; Kennedy et al, 1970; Newell and Simon, 1972; Webb, 1975).

Later work included problem solving in 'practice' based situations; these included many fields of work such as marketing (Green and Rao, 1971; Cattin and Wittink, 1982), education (Edwards et al, 1987; Cohn, 1989; Higgs, 1991) and medicine (Elstein et al, 1978; Barrows and Tamblyn, 1980; van Crevel et al, 1986; Benner and Tanner, 1987; Orme and Maggs, 1993).

THE RELATIONSHIP OF THEORY TO PRACTICE

Deductive, inductive and hypothetico-deductive logic have been found to be used by subjects involved in problem solving activities, both general and medical (Elstein et al, 1978; Groen and Patel, 1985). In addition, both heuristics and intuitive reasoning havebeen identified (Patel et al, 1986; Orme and Maggs, 1993).

Deductive reasoning

Both Braine and Rumain (1983) and Rips (1983) have reviewed a number of studies which indicate that adults use deductive logic in life situations and later studies have confirmed these findings. Examples drawn from the literature which reports on clinical reasoning processes include the work of Kuipers and Kassirer (1984) and Patel and Groen (1986), who identified propositional logic, employing 'if-then' statements, in their studies.

Many difficulties exist with this form of thinking, which is open to mistakes in reasoning (Johnson-Laird and Bara, 1984). Chapman and Chapman (1959) list a number of areas in which mistakes can occur. A subject may 'convert' a premise; upon hearing that all A's are B's, they assume therefore that all B's are A'. Subjects may reason in a probabilistic fashion; thus they provide answers that are likely to be true rather than must be true in terms of the logic. Henle (1962) argues that errors are frequently not the result of faulty logic but the result of a lack of understanding. She maintains that subjects behave as though they are required to judge the truth of the propositions rather than whether the conclusion follows from the given statements. A subject may misinterpret a premise, may add additional premises or omit a premise when examining the conclusion (Henle, 1962).

Johnson-Laird and his colleagues describe how the more complex syllogisms often require examination in a number of different ways before a correct conclusion can be deduced and postulate models of deduction for a variety of configurations (Johnson-Laird and Steedman, 1978; Johnson-Laird, 1983; Johnson-Laird and Bara, 1984). Problems requiring one model only are frequently solved correctly; however some problems require the subject to examine them in up to three different ways. Subjects rarely examine all such models and consequently make mistakes. Johnson-Laird (1985) and Gallotti et al (1986) also suggest that difficulties increase when the problem is not structured in the most obvious way, or one of the premises have to be inverted during the analysis.

Thus evidence exists for the use of deductive reasoning by adults in deriving decisions in daily activities but the process is fraught with difficulties and may lead to dubious conclusions.

<u>Inductive reasoning</u>

This form of reasoning is also used in practical problem solving. Howes (1990) states that 'we routinely make decisions as a function of what is likely to result from the decision; that is, on the basis of the probability of a certain outcome'. Induction is normally used to discover a logically valid conclusion, often after deduction has been employed to test the validity of the assertion (Ericsson and Simon, 1993). Thus initial deduction may occur in a novel situation but is followed by inductive processes in subsequent, similar situations. Such inductive processes may be achieved through recognition of similar occurrences or may be identified through the use of heuristics. Inductive reasoning is exemplified in studies which indicate the use of pattern matching or heuristics in problem solving (Gorry, 1970; Richards et al, 1993).

Hypothetico-deductive reasoning

Hypothetico-deductive reasoning, or hypothesis orientated inquiry, has been identified by many researchers working both in the laboratory and in the field. It has been shown by Gale (1982) to be a form of reasoning used by mature adults in many areas of life and of varying ages, abilities and experience, and has also been described in the medical problem solving literature by a number of authors (Elstein et al, 1978; Kassirer and Gorry, 1978; Barrows and Tamblyn, 1980; Fleming, 1991; Higgs, 1992).

Huesmann and Cheng (1973) were amongst the first to identify this method of reasoning in practice as subjects solved mathematical problems. They suggested that the process involved the use of a heuristically directed 'generate and test' search of hypotheses. The order in which the hypotheses were generated appeared to be independent of the data and, in general, the subjects started with the simplest hypothesis and moved on to the more complex. Subsequently, Elstein et al (1978) proposed a medical model of problem solving which again focused on the acquisition and evaluation of hypotheses. Barrows and Tamblyn (1980) and Fleming (1991) reported similar patterns of problem solving in medical practitioners and occupational therapists respectively.

Some authors suggest that hypothetico-deductive reasoning may be a sequential process (Elstein et al, 1978; Barrows and Tamblyn, 1980) whilst others believe that evaluation and interpretation of data is integral with its collection and is thus a cyclic process (Gale and Marsden, 1982; Jones, 1992a, b).

Heuristics

Heuristics have been described as 'rules of thumb' used by people during the reasoning process (Tversky and Kahneman, 1974; Baron, 1988). They provide general guidance for decision making and may include categories such as 'what if every one did that?', 'make sure that each paragraph has a topic sentence' and 'all sequences of equally likely events are equally likely to occur'. The use of heuristics to guide problem solving processes has been described as a useful way to proceed but offers no guarantee of success, possibly even leading to repeated, systematic error and low levels of performance (Tversky and Kahneman, 1974; Shanteau, 1988). Simon (1983), however, emphasised the need for such devices in practical decision making because of the limited cognitive processing capacity of the human brain.

Polya (1957) was among the first to postulate the use of heuristics in problem solving and provided a list which he considered to be used in practice. Tversky and Kahneman (1974) highlighted the frequent use of heuristics under conditions of uncertainty and identified three areas in which they believed these to occur; these were (a) representativeness, usually used when the subject is asked to judge the probability of an item belonging to a certain category; (b) availability of similar instances or scenario, used when subjects are asked to assess the frequency of an incident or plausibility of a development; and (c) adjustment from an anchor, which is usually employed in numerical predictions.

Both Kahneman et al (1982) and Shanteau (1988) believe that heuristics are extensively used by both novice and expert practitioners, many authors identifying their use in problem solving; Kilpatrick (1968) analysed the protocols derived during the resolution of word problems in mathematics by school children and identified the use of three distinct heuristics. These were drawing a figure, using successive approximations and questioning the existence and uniqueness of a solution. Goor (1974), Svenson (1974) and Montgomery (1977) all identified the use of heuristics in a variety of situations including mathematical, linguistic, gambling and house purchasing problems. Others view hypothetico-deductive reasoning as a response to a 'generate and test' heuristic (Groen and Patel, 1985).

Clinicians may also use heuristics to solve or avoid problems; for example, the heuristic 'if there is any chance of the disease being present the procedure must be performed', 'if it saves one person it must be worth it' and 'when in doubt, do it' can serve the purpose (Baron, 1988).

<u>Intuitive reasoning</u>

A number of studies, particularly in the area of nursing practice, highlight the importance of intuitive based reasoning (Young, 1987; Gatley, 1991;

Orme and Maggs, 1993). Benner and Tanner (1987) define intuition as 'understanding without a rationale' whilst Orme and Maggs (1993) report a definition of intuition developed at a work shop of experienced clinicians as 'a state of heightened perceptual awareness which emanates from subconscious thought. It influences behaviour and therefore influences the decision making process'.

Rew (1986) identifies three characteristics of intuitive reasoning; knowing a fact or truth as a whole, having immediate possession of that knowledge and having knowledge which is independent of linear reasoning processes. Benner and Tanner (1987) describe six key aspects of intuitive judgement as demonstrated by experienced nurses; these are pattern recognition, similarity recognition, commonsense understanding, skilled 'know how', sense of salience and deliberative rationality.

Some believe that such reasoning should be valued and the skill encouraged (Benner and Wrubal, 1982; Schrader and Fischer, 1986; Agan, 1987; Young, 1987; Gatley, 1992), whilst others believe that it has a limited place in clinical practice (Johnson; 1980; Robinson, 1985; Rew, 1986; Josefson, 1987). Benner and Wrubal (1982) and Young (1987) argue that there is a close relationship between experience and intuition and Orme and Maggs (1993), whilst reporting that experienced nurses endorse the importance of its use, suggest that there must be a close relationship between knowledge and intuition. Conversely, Ayer (1969) suggests that intuition only serves to disguise a lack of explanation. He concludes that there is no way of distinguishing between knowledge and belief, and that the reliability and validity of intuition are doubtful.

Despite such limitations, Gatley (1992) concludes that the strength of intuitive reasoning lies in its place within clinical practice, embedded within knowledge derived in the practical situation and Benner and Tanner (1987) emphasise that it is not a question of either rational or intuitive decision making but a combination of the two.

THE ROLE OF KNOWLEDGE IN PROBLEM SOLVING

Recent research places an increased emphasis on the importance of the relationship between knowledge and problem solving; work has shown that the relevance and depth of knowledge and the ability of the subject to structure and organise the material into meaningful patterns is of importance in the problem solving process (Bordage and Lemieux, 1986; Grant and Marsden, 1987; Norman, 1988; Grant et al, 1988). Prior to this many workers believed that problem solving skills could be learned in isolation from discrete knowledge, and research and education focused on examining and fostering general strategies and abilities (Johnson, 1955; Polya, 1957); at this time the role of knowledge and its structuring were played down.

De Groot (1965) was the first to note that in his studies, reasoning styles and skills did not appear to distinguish between expert and novice chess players. The main difference seemed to lie in the recall of meaningful board positions; he deduced from this that the key to expertise might lie in the content and structure of knowledge. This result was reproduced by Elstein et al (1978), Pople (1982) and Clancey and Shortcliffe (1984) who showed that an extensive knowledge base was essential to successful reasoning whilst Larkin (1980) showed that experience affected the processes. Patel and colleagues (1984; 1986) showed that those with a greater knowledge base made more use of inference from prior knowledge and that they tended to recall information in larger segments.

A number of studies have shown that the organisation of knowledge in the long term memory is crucial to successful problem solving. Reports have suggested that information is grouped into categories and may be structured around a 'prototype' which captures the meaning of the category (Bordage and Zacks, 1984). It is thought that prototypes include the main features that are common to the elements in the category. Cantor et al (1980), Horowitz et al (1981a,b) and Bordage and Zacks (1984) suggest that health professions do in fact organise medical information in this way. Prototypes may then guide the clinician to relevant knowledge and form an indexing system to other related members of the category (Bordage and Zacks, 1984).

Both the content and structure of the knowledge available to the clinician is therefore believed to be of great importance in problem solving; experience in some way as yet not understood appears to assist in the process of categorisation and therefore access (Bordage and Zacks, 1984; Norman et al, 1985).

MODELS OF CLINICAL PROBLEM SOLVING

The process of reasoning has been described by psychologists in terms of global principles such as search and inference (Baron, 1988), with the work of Newell and Simon (1972) on the theory of human information processing providing a possible rationale to underpin both ideas and the research designs developed to test them.

Doran (1984) and Baron (1988) highlight the numerous ways in which problems may be solved and note that the same method will not be suitable for all situations. Doran lists habit, standard procedures, prejudice, rationalization, pattern recognition and hypothetico-deductive reasoning whilst Baron details simple trial and error techniques, 'hill climbing' (which is a modified form of trial and error that incorporates some feedback in response to trials), means-end analysis (in which greater information is available about the possible outcome of trials resulting in each being less blind than in the previous methods), and the use of subgoals and working backwards from the desired result to find a solution.

In 1972, Newell and Simon identified three, fundamental problem solving strategies used by subjects in a variety of experimental situations; these were recognition, generation and testing, and heuristic search. Many other researchers expanded these categories; Goor (1974) proposed seven categories to describe think aloud protocols. These were:

a. surveys give information
b. generating new information or hypothesis
c. developing hypothesis
d. unsuccessful solution
e. changing the conditions of the problem
f. self-reference or self-criticism
g. silence

Newell (1973) and Groen and Patel (1985) talk of 'weak' and 'strong' methods of problem solving. Weak methods are based on the use of a general heuristic and are broad in their application; however, when implemented on a computer they were found to be inefficient. Feltovich and Borrows (1984) identify hypothetico-deductive reasoning as a weak method based on the heuristic of 'generate and test' and whilst Newell (1973) considered means-end analysis to be of a similar form. Strong methods, which make use of knowledge, are in contrast highly successful but problem specific. Groen and Patel (1985) emphasise that little is known about these methods but conclude that they involve the use of highly organised knowledge and are employed by experts.

Through the conduct of research studies, a number of models having been developed to describe the clinical reasoning process. Some models have been formulated by educationalists with the specific purpose of teaching problem solving skills to students; others have been developed with a view to explaining how practising clinicians address problems and to facilitate improved performance thorough educational or technological means. Diagnostic skills, decisions about patient management and selection of treatments have all been examined.

The diagnostic process has been examined and described in a number of ways which have included forward, backward and vertical reasoning; pattern recognition, the use of production rules and the use of heuristic rules and constraints have been suggested by some (Gorry, 1970; Barrows et al, 1978; Groen and Patel, 1985; Patel et al, 1986; Richards et al, 1993); others have proposed mathematical and logical models (Gorry, 1970; Schwarz et al, 1973; Dawes, 1980; Arkes et al, 1986; Wigton et al, 1986) and Lemieux and Bordage, in reports in both 1992 and 1993, suggested the use of vertical reasoning which highlights the semantic differences in texts. Over the years the use of hypothesis generation and testing has been emphasised in medical problem solving (Barrows, 1976; Elstein et al, 1978; Barrows and Tamblyn, 1980; Payton, 1985; Fleming, 1991).

Perhaps the most influential medical model in recent years was proposed by Elstein and colleagues who developed a model of medical inquiry (Elstein et al, 1978). This is a hypothetico-deductive model and consists of four stages; (a) cue acquisition, (b) hypothesis generation, (c) cue interpretation and (d) hypothesis evaluation. Clinicians were shown to develop and test single or competing hypotheses, using inductive reasoning methods. This process resulted in the tailoring of data collection.

Cue acquisition is initiated by history taking and may include routine data collection. Hypotheses are triggered by clusters of cues or a single salient cue and chosen on the basis of opposing formulations, availability or when experienced as 'vivid and salient' (Tversky and Kahneman, 1974). Leaper et al (1972) noted that errors exist in the subjective-probability assessments of clinicians. Cue interpretation occurs in the light of the hypothesis being tested. Informal weighting is applied to each element with the result that cues may suffer confirmation, disconfirmation or be regarded as noncontributory. Errors can arise during this weighting process and are due to a failure to manipulate large volumes of data (Gill et al, 1973). Hypothesis evaluation is a process of weighing up the 'pros and cons' for each hypothesis.

A similar model was proposed by Eddy and Clanton (1982) containing the following stages; aggregation of elementary findings, selection of a pivot (or pathognomonic finding), generation of a cause list, pruning of the cause list, selection of the diagnosis and validation of the diagnosis. This work was based on the interpretation of clinical reports presented in the New England Journal of Medicine by both experienced medical practitioners and students.

In contrast a number of researchers have suggested that the problem solving process, especially in experienced clinicians, is primarily a matter of pattern recognition or the use of production or heuristic rules (Groen and Patel, 1985; Rabinowitz and Glaser, 1985; Patel and Groen, 1986;

Richards et al, 1993). In pattern recognition the clinician compares the patient's problem with a known disease pattern or patterns. The most appropriate is elected - often very early in the interview - and pursued with a view to confirmation. This model is inductively based and assumes the prototype model of knowledge organisation discussed previously (page 284).

Production rules involve the use of a series of <u>if</u>/<u>then</u> rules; <u>if</u> a certain antecedent condition is met <u>then</u> a specific consequence follows. In familiar situations immediate conclusions may be drawn; in other more complex instances inferences are made by combining conclusions. No hypotheses are generated by this method which is a 'forward' or inductive process. Heuristic rules, on the other hand, involve the use of demands or constraints which guide the process. In order to generate and apply the production and heuristic rules the clinician draws on their knowledge base; the more extensive and structured that knowledge base, the more effective and efficient is the problem solving process. However, as the problems become more complex, some deductive, backward reasoning may be used (Patel and Groen, 1986).

There is much discussion in the literature about the merits of each of these major models. Barrows and Feltovich (1987) believe that methods other than the hypothetico-deductive trivialise the clinical reasoning process. They claim that in realistic situations, in which a problem <u>unfolds over time</u>, pattern recognition is unlikely. They believe that it is only through the hypothetico-deductive method that initial information can be elicited from the subject and data collection tailored to that subject and suggest that the pattern recognition model may be an artifact resulting from study designs which present the respondent with a complete or almost complete case history at the onset. These writers claim that 'what looks like pattern recognition .... will invariably reveal hypothetico-deductive inquiry' (Barrows and Feltovich, 1987). In contrast, Groen and Patel (1985) believe that the hypothetico-deductive model may equally be a design artifact; the use of retrospective and introspective techniques, as in the studies of both Barrows and his associates (Barrows and Tamblyn, 1980; Barrows et al, 1982) and Elstein (Elstein et al, 1978), can lead clinicians into developing reasons to account for their behaviour. Again Lemieux and Bordage (1993) contrast propositional and structural semantic analysis and suggest that the former identifies and examines the surface structures of the process whilst the latter addresses the deeper, linguistic structures.

Some overlap between these various views may, however, exist; Elstein et al (1990) and, to a lesser extent, Groen and Patel (1985) suggest that in experienced clinicians dealing with routine problems pattern recognition may be common, though they suggest it is rare in novice clinicians and in complex situations when hypothesis-led problem solving is the norm. It has been suggested that the present emphasis on hypothesis-led models may arise from early studies, based on the belief that problem solving was a universal skill separate from knowledge; many early investigations employed novel problems and naive (novice) problem solvers.

In addition to these studies and models, problem solving models have been developed which relate specifically to the work of remedial therapists. Some of these fall into one or other of the models described above, though others do not. Fleming (1991) identified four types of reasoning used by occupational therapists when evaluating and treating clients; these were narrative, procedural, interactive and conditional reasoning. When selecting treatment activities the therapist employed procedural reasoning which involved the practitioner in problem definition and treatment selection. Problem identification, goal setting and treatment planning were identified by the subjects as the major components of the procedure. Fleming notes that they utilised both the problem solving methods identified by Newell and Simon in 1972 (recognition, generation and testing and heuristic search) and those identified by Elstein and his colleagues (cue identification, hypothesis generation, cue interpretation and hypothesis evaluation). The methodology used involved videographic taping of treatment sessions and retrospective discussion of these tapes.

A number of models have been developed with a view to enhancing problem solving in the education of physical therapy students, some being based on theoretical considerations rather than observed practice. May and Newman (1980) described a model for use in education, basing it on behaviours described in cognitive, affective and psychomotor taxonomies. They listed seven steps: (1) problem recognition, (2) problem definition, (3) problem analysis, (4) data management, (5) solution development, (6) solution implementation and (7) outcome evaluation.

Olsen (1983) described a similar model, which in turn was based on the work of Day (1973) who used the model in the education of occupational therapy students. The model developed by Olsen (1983) includes the stages of (1) cause, (2) problem, (3) method, (4) solution, (5) product, (6) modality and (7) goal. Echternach and Rothstein (1983) developed an eight part model, again for use in education; the steps include (1) collection of initial data (history taking), (2) problem statement (chief complaint) and goal setting, (3) physical examination, (4) working hypothesis related to goals, (5) treatment strategy based on hypothesis, (6) specific treatment methods, (7) implementation and (8) reassessment. These, and other similar models (May, 1977; Barr, 1977; Day, 1973; Perry, 1981), are largely based on a theoretical understanding of the processes of problem solving.

An alternative approach bases the development of models on processes observed in experienced clinicians. The objective of these models is often both to facilitate clinical education and improve problem solving in practicing clinicians. Payton (1985) examined the problem solving strategies used by experienced physical therapists in a number of different specialities using the same methodology as Elstein et al (1978). He concluded that therapists used similar problem solving strategies to the medical staff examined by Elstein and colleagues (1978) and those who later examined his model (Barrows and Tamblyn, 1980; Gale, 1982; Barrows and Feltovich, 1987). He reported that physiotherapists examining a variety of patients identified hypotheses in the areas of pathology, pathokinesiology, pathophysiology and psychosociology.

Higgs (1991) and Jones (1992a) examined problem solving in physiotherapists as they assessed and selected treatment for patients requiring manipulative therapy. Jones (1992a) believed that some difficulties arose when applying the hypothetico-deductive model postulated for medical diagnosis to physiotherapy examinations and expanded it to better describe the reasoning processes used by physiotherapists. He suggested that the **types** of hypothesis developed by physiotherapists differed from those developed in medical diagnosis and listed the following alternative categories: (1) source of symptoms or dysfunction, (2) contributing factors, (3) precautions and contraindications to assessment and therapy, (4) management and (5) prognosis. Jones (1992a,b) also believes that the basic hypothetico-deductive model posed by Elstein et al (1978) requires some modification if it is to describe physiotherapy practice; he represents the reasoning process as cyclic and expands it to include aspects of intervention and reassessment.

It should be noted that Jones (1992a) briefly suggests that pattern matching may be common in experienced physiotherapists; however, all these researchers focus primarily on the presence of hypothetico-deductive reasoning and suggest that it is the primary method used.

CONCLUSION

Problem solving, the practical outcome of logic, has been studied for many years; subjects with a wide variety of expertise and different levels of experience have been studied as they solve problems of many types. Much early work involved the use of novel problems, presented under laboratory conditions and were based upon the belief that problem solving capabilities were domain free. Such work led to the suggestion that much problem solving was of a hypothetico-deductive nature. This view was later confirmed in the medical arena by researchers such as Elstein et al (1978) and Barrows and Feltovich (1987); in addition Payton (1985) and Jones (1992a) postulate that physiotherapists also use the method in their work.

However, others have questioned this view and suggest that though novices and expert presented with novel problems may use hypothetico-deductive methods, experienced practitioners frequently use other techniques involving forward or vertical reasoning.

PURPOSE OF THE CURRENT STUDY

Section II of this thesis has demonstrated that electrotherapy is widely used by physiotherapists in the management of soft tissue lesions. In addition the study revealed a number of factors which subjects reported affected their selection of treatments. These surveys, however, were unable to provide information about the problem solving strategies used to select individual agents.

Selection is a complex task involving both the evaluation of the patient's current health status and an understanding of the behaviour of the agents in question. Therapists are confronted by uncertainty in both areas of knowledge but nevertheless are required to evaluate and treat their patients on a daily basis.

Despite these problems, selection and usage must depend on the decisions reached by physiotherapists as they examine their patient and the problems they identify during the problem solving process. There is therefore a great need for therapists to use recognised scientific methods to evaluate the examination and treatment selection processes used in clinical practice in order to assist the learning of novice therapists and improve the performance of more experienced practitioners.

The study reported here was designed to identify some of the specific tactics and general strategies constituting the problem solving behaviour of the experienced physiotherapist when engaged in the examination of patients with soft tissue injuries. In addition, the study would examine the decisions made as a result of that examination, with particular attention being paid to the selection of electrophysical agents.

The aims of the present study were:

* to examine the general problem solving processes used by experienced physiotherapists when solving a common soft tissue problem

* to identify the use of specific hypothetico-deductive problem solving strategies by experienced physiotherapists when solving a common soft tissue problem

* to examine the decisions made by experienced physiotherapists when solving a common soft tissue problem

The following hypotheses would be tested:

* experienced physiotherapists use the same gross problem solving strategies to solve familiar problems as other professional people

* experienced physiotherapists use hypothetico-deductive methods to solve familiar clinical problems

* the problem solving strategies used by experienced physiotherapists to examine two common conditions are similar

* experienced physiotherapists make similar clinical decisions for each case study

The following chapter will examine the research methods and designs which could be used to address these questions and identify those most suited to the aims of this study.

Section III. Chapter 2.

AN EXAMINATION OF PROBLEM SOLVING IN PHYSIOTHERAPY PRACTICE: AN EVALUATION OF RESEARCH METHODOLOGIES

Examination of the clinical problem solving (CPS) used by physiotherapists poses a number of difficulties. Whilst outcome may be self evident, process is difficult to examine and describe for a number of reasons; it occurs in the mind of the subject and is thus not easily accessible to the researcher, therapists are often unclear about or unaware of the processes they employ, the diversity of conditions confronted is great and the therapist frequently functions under conditions of uncertainty (Benner and Tanner, 1987; Shanteau, 1988; Elstein et al, 1990). It is, nevertheless, important to examine both aspects if the decisions made and the rationale underpinning those outcomes is to be eventually understood and practice enhanced at both the graduate and undergraduate levels.

This study focuses on both the process used and the outcome of clinical problem solving by physiotherapists treating soft tissue lesions. Quality of judgement will not be formally examined, though the reported outcomes will be discussed in the light of the theory provided in section I of this thesis.

Process and outcome may be examined together or separately (Elstein et al, 1990). Together they are commonly examined through the use of process tracing methods whilst utility valuation methods are normally selected to examine outcome alone. Process tracing methods have been described as both descriptive and explanatory whilst mathematical methods may be either descriptive or prescriptive, depending on the form used (Elstein et al, 1978).

The indications for, benefits of and problems with each of these methods will be considered in the following sections.

PROCESS TRACING APPROACHES (DESCRIPTIVE METHODS)

A number of methods used in CPS studies describe the thinking processes used by subjects. These methods aim to examine both the information search and information integration aspects of problem solving and to model what goes on inside the mind of the subject (Baron, 1988). From the information gathered theoretical models of reasoning may be developed, their purpose being to describe and subsequently aid clinical practice. These rely on inductive inferences being made from the data, general rules being formulated from specific responses (Einhorn et al, 1979; Ericsson and Simon, 1993).

The main advantage of process tracing methods is that theory and method exercise less control over the data collected than in mathematical models which examine outcome alone, as they depend on direct observation and analysis of clinical performance. This, Elstein et al (1990) believe, increases their validity and generalisability and in turn increases both face validity, particularly with respect to the implementation of their findings amongst practising clinicians, and content validity with respect to experienced clinicians and the literature in the area (Elstein and Bordage, 1988; Bala et al, 1989). The method may be used to examine whole or parts of a task and is suitable for the examination of both complex and simple problems. In addition, it facilitates the replication of the clinical task in question to varying degrees, depending on the method used.

A number of research designs are available to implement this type of study. Direct observation of behaviour can be performed, or written records of decision making processes can be examined, but these methods are rarely employed in clinical problem solving studies. Verbal traces, derived either during or after a problem has been addressed, are the method most often used.

Direct observation

This method focuses primarily on outcome rather than process and, though some sequential visual information is available to the researcher throughout the procedure, the thought processes underlying the actions of the subject are inaccessible.

To date this design has been used mainly in experimental, non-clinical problem solving. The subject may be directly observed during the performance of a problem solving task or videographic records made of the incident which are examined at a later stage. Physical activities such as hand and eye movements or gross motor performance may be observed. For example, Loftus and Bell ((1972; 1975) and Payne et al (1988) examined picture recognition and information gathering respectively through monitoring eye fixation and motion as subjects examined pictures and information sheets.

This method has been shown to be satisfactory when the target viewed lacks complexity; Loftus (1972), for example, ensured that the letters in the puzzles were adequately spread to allow individual fixation to be noted. Verbal reports of performance and observed eye movement have been shown to correlate well in such situations. Kaplan and Schoenfeld (1966) demonstrated perfect correlation between eye movements and reported awareness of possible permutations when solving simple permutation anagrams, and Winikoff (1967) showed that predicted and observed fixations agreed at significance levels of 0.01 and beyond in the examination of eye movements during the resolution of mathematical, chess and letter problems.

Observational methods are not normally, however, satisfactory for use in 'real life' situations as it is extremely difficult to establish the reliability and validity of the evaluation process, owing to the complexity of the action. This method is not, therefore, appropriate for the examination of problem solving in a clinical setting.

Analysis of records

This method involves the analysis of verbal data which has been recorded in writing, normally for some other purpose. It is, however, only feasible when the material is very detailed as when verbatim transcripts of verbal exchanges has taken place. An example is the work of Janis (1982) who analysed the committee papers concerning the policy decisions which led to the Bay of Pigs invasion of Cuba in 1961.

This method is generally not suitable for the examination of medical records; those kept by therapists normally record an abbreviated account of an assessment or treatment programme and, as with all retrospective data, is subject to limitations associated with missing material and the varied needs for which the records were originally constructed. For further discussion of the issues surrounding the use of retrospective data see section II, chapter 2.

Verbal traces

By far the most common method of examining the processes inherent in problem solving is to ask subjects to talk through a task (Baron, 1988; Elstein and Bordage, 1988; Ericsson and Simon, 1993).

As is the case with all process tracing designs, verbal traces involve the serial acquisition of information by the subject, though the way in which this information is collected varies greatly according to the level of control exerted over the trial by the researchers. Probes are used to direct the process. 'Think aloud' probes simply ask the subject to verbalise all their thoughts as problem solving occurs; introspective probes require the subject to identify a variety of factors, such as hypotheses, which the researcher believes may guide their thoughts or actions, or may ask for reasons for behaviour. This is normally in addition to 'think aloud' verbalizations. Finally retrospective probes may be used after the subject has completed the task; again the subject is normally asked to identify reasons for actions and statements and explain in greater detail what they were thinking and doing (Ericsson and Simon, 1980; 1993).

Some studies examine the process as it is performed with actual patients, normally employing videographic techniques to record the event and developing a retrospective verbal trace after the event (Payton, 1985; Fleming, 1991). Others have found this method impractical or impossible to control and have therefore used alternative situations. Elstein et al (1978) and Barrows and Tamblyn (1983) describe the analysis of protocols derived from 'high fidelity' contexts in which actors are used to simulate patients and the environment adapted to replicate a clinical setting. Other studies, both by these authors and others such as Kassirer and Gorry (1978) and Eddy and Clanton (1982) have used more structured designs. For example, information may be read to the subject as required or read by the subject; information may be presented in a preset sequence or may be limited to certain aspects identified by the researchers. All of these designs have advantages and disadvantages. Barrows and Feltovich (1987) strongly advocate the use of an open approach; they emphasise the importance of clinical reality, criticising the external validity of approaches which do not allow the clinician to select the data they require, determine the sequence in which that data is acquired and allow temporal unfolding of the study; both live contexts and simulations facilitate this approach. Conversely, authors such as Moskowitz et al (1988) and Grant and Marsden (1987) believe that reliability, validity and repeatability can only be assured when the study design controls information delivery more fully. They strongly believe that one off situations, as found in clinical practice, should be avoided.

It has been suggested that the production of verbal traces may distort the normal problem solving process; Nisbett and Wilson (1977) propounded this view after reviewing a number of papers, the majority of which utilised retrospective probes. Evidence suggests, however, that simple 'think aloud' traces are unlikely to modify the thought patterns of a subject. A number of studies indicate that, though greater time is required to perform the task, cognitive processes remain stable in terms of accuracy of performance and strategies used (von Borstel, 1982; Deffner, 1984, 1989; Rhenius and Heydemann, 1984; Heydemann, 1986). Introspective and retrospective probes may, on the other hand, modify the thought trace in some way as the subject is required to interrupt, and often interpret, their thinking (Gagne and Smith, 1962; Davis et al, 1968; Wilder and Harvey, 1971; Ericsson and Simon, 1993).

Whilst such modifications may alter the processes normally used by the subject there is some evidence to suggest that when subjects are asked to verbalise reasons and explanations whilst performing the task their problem solving performance may improve (Berry, 1983; Stinessen, 1985; Ahlum-Heath and Di Vesta, 1986). Thus the process may be altered but outcome improved. Hagafors and Brehmer (1983) found that the instruction to justify a judgement led to an increase in consistency of performance in a multiple cue probability learning task, a fact which Ericsson and Simon (1993) suggest may be of considerable educational importance for the learning and performance of tasks.

Summary

The descriptive, process tracing method of analysis renders explanation and understanding of the process undergone during CPS. A major advantage of this design is that it is isomorphic in its intention; it describes the process undergone. The method accesses the thoughts of the subject at the time when they occur and allows the participant to communicate directly with the researcher revealing otherwise inaccessible information.

The conceptual frame work underpinning it closely relates to the information processing view described in the psychological literature, theories of memory, cognition and language and logic (Elstein et al, 1990).

These theories provide a basis for assessment of the construct validity of the method (Ericsson and Simon, 1993).

Process tracing methods are non-experimental, non-statistical designs which render descriptions which are primarily amenable to descriptive analysis. It is, however, a time consuming process and there is, therefore, a limit to the number of subjects who can be accessed and the number of problems which can be examined (Elstein and Bordage, 1988); Moskowitz et al (1988), for example, used three subjects to examine one case. Given that subject performance differs (Grant and Marsden, 1987), and there is evidence to suggest that problem solving may be case specific (Groen and Patel, 1985), Elstein and colleagues (1990) highlight the need for increased numbers in each area.

Currently rules of analysis vary from one research group to another, each matching their analysis to their designs and objectives. Whilst this is justified on an individual basis, it poses problems for the comparison of results between groups. However, Elstein et al (1990) doubt that the discipline is advanced enough as yet to demand an adherence to uniform methods of analysis.

Process tracing designs are of particular value at the early stages of research into the process of CPS and may be used prior to mathematical studies to examine outcome; they facilitate the identification of factors which may influence decisions which may then be examined in further detail through the use of designs described in the following section.

MATHEMATICAL APPROACHES

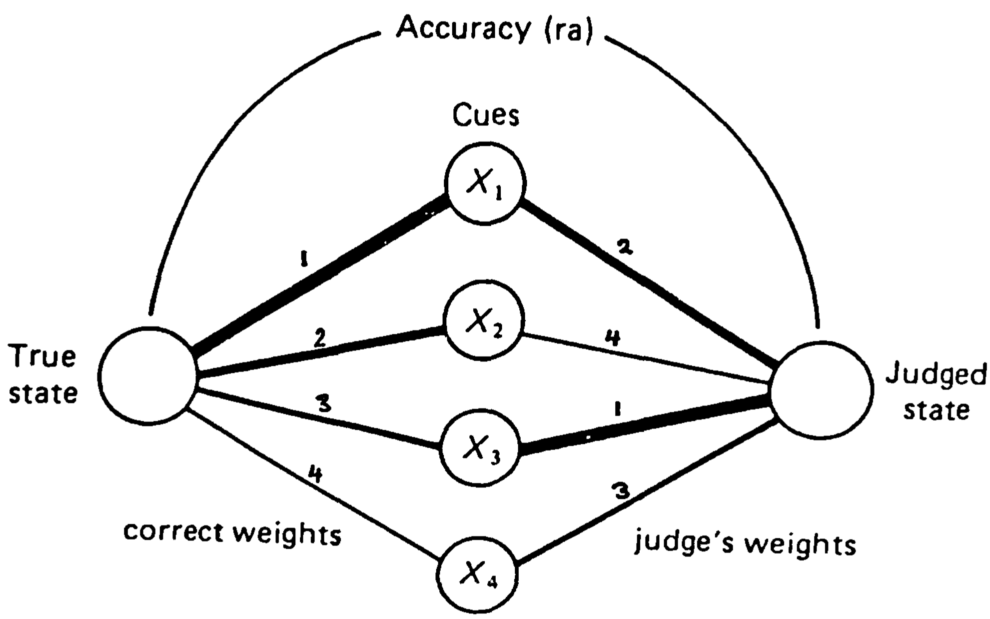
A number of mathematical methods are available to examine the outcome, or results, of the problem solving process. These methods, often termed 'black box designs', do not attempt to describe the information processing strategies employed by the clinician but analyze the decisions made and the factors these decisions have been based upon; they examine the relationship between input and output and have been used to describe information combination in problem solving (Einhorn et al, 1979). These models are developed deductively and are an attempt to capture a general strategy embedded on a theory of judgement (Brunswick, 1952).

Two types of design may be used; firstly, multivariate techniques which include regression equations (both linear and non-linear) and lens models may be used to examine the weighting given to selected cues when making decisions. Secondly Bayesian techniques, which calculate the subjective, and occasionally objective, probability weightings of cues may be used.

Multivariate techniques

Both linear and nonlinear models have been used to represent decisions. The Brunswick lens (figure 7) is an example of a model making use of linear regression equations to depict outcome (Brunswick, 1952; Hoffman, 1960; Dawes and Corrigan, 1974; Einhorn et al 1979) whilst conjoint analysis makes use of non-linear equations to depict decisions (Orkin and Greenhow, 1978; Nie et al, 1980; Richardson et al, 1984; Wigton et al, 1986).

Figure 7. The Brunswick Lens model



Regression equations have been used to capture human performance with considerable success and are regarded by some as the optimal model for this purpose; they are frequently more reliable over time than the human problem solver they model and can therefore be used to assist clinical decision making (Einhorn et al, 1979). Thus they describe and prescribe.

The primary elements required for this model include (1) a list of information such as cues, findings or attributes, (2) the calculation of their relative importance, or weighting of the elements and (3) the examination of functional relationships through the use of combination rules. A regression equation is computed using these judgements as the independent variable and the result is said to have captured the judgement of the individual (Hoffman, 1960; Slovic and Lichensten, 1971; Einhorn, 1974; Cook and Stewart, 1975).

In the linear model, judgements can be formulated as a weighted sum of the values of the information given; thus

$$Ys = Co + w1X1 + w2X2 + \dots + wkXk$$

where

Ys = the judgement

X = the different pieces of information available

w = the relative weights

Co = a constant

A number of correlations may be examined:

1. Ra - correlation between true and judged states.
2. Re - measures the predictability or uncertainty of the criterion that is being judged.

3. Rs - indicates how well a set of judgements can be predicted by a weighted linear combination of cue values (capturing the judges policy).

4. G - knowledge of the environment is the correlation between regression predictions of reality and the judgements.

These four correlations may be related in a linear fashion in the lens model equation:

$$Ra = G.\ Re.\ Rs$$

The accuracy of the model (Ra) is limited by the degree to which the task is predictable (Re), the knowledge of the properties of the task (G), and cognitive control over utilisation of knowledge (Rs).

A number of researchers have suggested that the linear model might be inadequate to represent the complexity of problem solving and suggested models which account for the possibility of judges interpreting items of information as contingent upon others. Non-linear models, for example incorporating exponential components, have therefore been proposed and have the property of being able to portray nonlinear variation within attributes (Hoffman, 1968; Goldberg, 1971; Einhorn, 1972; Orkin and Greenhow, 1978; Richardson et al, 1984).

An example of such a method is conjoint analysis, the method being initially developed for use in market research (Green and Rao, 1971; Green et al, 1972; Cattin and Wittink, 1982) and later adapted for use by those examining clinical outcome (Orkin and Greenhow, 1978; Richardson et al, 1984; Wigton et al, 1986). The technique is described in detail by Green and Wind (1973) and Nie et al (1980).

Two important assumptions are made with these techniques; firstly it is assumed that the construct can be defined in terms of a limited number of important characteristics. Secondly, it is assumed that the subject makes a decision on the basis of trade-offs between characteristics; the subject determines which characteristics are important and which are not.

There is currently little evidence that non-linear analysis is superior to the linear forms (Goldberg, 1971; Elstein et al, 1990) and that large numbers of cues are necessary. Elstein and colleagues (1978; 1990) suggest that this may be because people normally perform the task in a simple fashion; we simply weighs the salient cues and computes, or adds, the outcome.

Bayesian models

Outcome has also been predicted through the use of Bayes theorem. This model has been employed most frequently in medicine to assist clinical decision making with respect to diagnosis (de Dombal, 1984; Balla and Elstein, 1984; Sox, 1985; England et al, 1987). The Bayesian system is based upon the assumption that clinicians deal with incoming information in a sequential fashion and that they integrate information as it is received (Sox et al, 1988; Balla et al, 1989).

Balla et al (1989) identify the two main tasks performed through the use of Bayes theorem: (1) calculation of the probability of a condition being present or treatment being appropriate given certain clinical findings and (2) revision of that probability following acquisition of new information.

Bayes theorem was developed by Thomas Bayes (1702-1761) and may be represented as follows:

$$p[D|+] = \frac{p[D] \times p[+|D]}{\{p[D] \times p[+|D]\} + \{p[noD] \times p[+|noD]\}}$$

where: $p[D|+]$ = probability of disease conditional upon test result

$p[+|D]$ = probability of a test result given the subject is diseased; 'true positive rate'

$p[+|noD]$ = probability of the test result given the subject is not diseased; 'false positive rate'

In a Bayesian system a data base, normally derived from clinical experts and literature on the subject, is used to calculate the likelihood ratios of a set of factors in relation to a specific diagnosis or selection of treatment. Each of these indicants, or factors, must be mutually exclusive. Likelihood ratios are then multiplied to generate the probability of a subject presenting with a specific set of indices having a specific condition or requiring a particular treatment. It is important to note that the predictive value of each index is influenced by the prevalence of the condition in the general population and the sensitivity and specificity of the factor itself; thus the calculation for each subject is started from a position of prior probability, representing general prevalence, and the evidence observed in the individual.

Summary

These techniques have been widely used to examine, model and predict with respect to medical diagnosis and, to a lesser extent, patient management. They may be applied in a wide variety of situations, both clinical and non-clinical and used to model group decisions as well as individual decisions.

Recent work has suggested that multivariate techniques capture the judgements of subjects in a reliable fashion (Dawes, 1980; Eddy, 1984). Bayesian techniques are a particularly successful method of revising opinion following the acquisition of new information during clinical evaluations that present data in a serial fashion over time - a situation reflective of normal daily practice. There is presently evidence to suggest that human decision makers alone are poor at this, ignoring cues they perceive as unimportant or not fitting with their current work up of the problem (Elstein et al, 1978).

Both methods may be used to improve the accuracy of clinical decision making, to increase knowledge and improve the consistency of clinical judgements. Studies using the lens model to provide feedback to medical studentsabout their problem solving activities have shown that they can provide excellent support, thus facilitating future decision making (Rappoport and Summers, 1973). Their efficacy in this way may suggest that this method reflects accurately the processes used by human decision makers.

Though this type of study has been shown to demonstrate reliability in a variety of situations, questions have been asked about its validity. In order to proceed with the first method, cues or factors must be identified; this is normally done through the literature, through brain storming sessions with practitioners or through the use of the descriptive techniques already described. Their identification is not always easy as there is evidence to suggest that subjects find it difficult to identify specific cues used to problem solve. Nevertheless, salient, mutually exclusive cues are essential to the success of both techniques.

Factors examined by these techniques must be mutually exclusive; this can mean that, especially in medical practice, certain interdependent factors have to be omitted in order to prevent distortion of the results (Richardson et al, 1984). Numbers of cues may also have to be reduced in the experimental situation leading to the need to identify those which are the most salient. In addition, many procedures demand that all combinations of factors be considered with the result that unlikely groupings can arise. All of these points can result in distortion of normal practice and possible of outcome.

Similar problems arise when calculating probabilities for the Bayesian technique; most probability levels are calculated for clinical purposes through subjective means, experienced clinicians being employed. Occasionally objective information is available. Again factors must be identified, be mutually exclusive and may have to be reduced in number.

CONCLUSION

A number of authors have suggested that mathematical techniques in general are too simplistic to capture the highly interactive and contingent methods which are thought to be used in clinical problem solving (Polanyi, 1967; Schön, 1983, 1992; Dryfus and Dryfus, 1986). These authors advocate the use of descriptive methods which they believe to be essential if the process is to be adequately captured. Some suggest that numerical models may lack face validity with both clinicians and researchers lacking mathematical sophistication (Balla et al, 1989). In contrast, Einhorn et al (1979) and Balla et al (1989) argue that though the mathematical model may not be isomorphic with the process it is modelling, it captures the highly interactive nature of the process within a very different structure.

These authors suggest that the descriptive and statistical models may not be as different as they seem and suggest that the designs reflect differences in 'emphasis and descriptive level of detail' rather than underlying process (Einhorn et al, 1979). Examination of the concurrent validity of both methods has tended to confirmed this view (von Borstel, 1982; Deffner, 1984; 1989; Rhenius and Heydemann, 1984; Heydemann, 1986).

As the aim of this study was to examine both process and outcome, both descriptive and mathematical designs were options. The advantages and disadvantages of each were therefore examined.

Initially it was believed that statistical methods would provide a more objective description of the way physiotherapists solve clinical problems with respect to soft tissue lesions. Multivariate techniques which provide information about process and outcome were first considered as a reliable and repeatable way in which to achieve the objectives of the study.

Early investigative work was carried out with a view to using either linear regression techniques or the conjoint method. As work progressed it became clear that a limited number of factors could be examined. The reliable and valid identification of mutually exclusive factors posed major problems as clinicians were unable to identify or prioritize those which were most salient. This may relate both to uncertainty within the field of electrophysical treatments and to a more general trend identified by

Tversky and Kahneman (1974) which suggests that clinicians frequently fail to identify salient cues.

Methods of examining outcome, based on the Bayesian theorem, were also considered but rejected as generation of the necessary probability levels again posed problems; both inter- and intra-rater reliability with respect to developing probability levels was low.

It was therefore decided that a descriptive method would be more appropriate at this stage in the examination of the problem solving strategies used by physiotherapists and therefore for the present study. The method would both provide information about process and outcome and facilitate the development of information which could subsequently be used to develop models, both descriptive and prescriptive, to augment the decision process. The method could also facilitate the later use of mathematical designs to examine outcome.

Concurrent verbalisation was selected as the most reliable method of data gathering, reducing the interpretive element commonly found in descriptive studies making use of retrospective and interpretive probes. This method has the advantages of depending directly upon the observation and analysis of clinical practice, leading to high levels of acceptability with clinicians. It is less dependent on theory and method for its validity than statistical methods, though Ericsson and Simon (1993) state that theoretical validity is afforded this form of analysis as it relates closely to the concepts underpinning the information processing view of cognition. Finally, the data collected is less likely to be distorted due to the imposition of statistical modelling.

The following chapter describes the development of the tools used in this study and implementation of the study.

Section III. Chapter 3.

CLINICAL PROBLEM SOLVING IN PHYSIOTHERAPY: SELECTION OF TREATMENT FOR SOFT TISSUE LESIONS

The primary purpose of the present study was to identify and examine the general strategies and specific tactics used by experienced physiotherapists when engaged in assessing patients with soft tissue lesions, developing appropriate management strategies and selecting specific treatments. In addition, the nature of the decisions made by these physiotherapists is addressed.

I. DEVELOPMENT WORK

A process tracing method, employing concurrent verbalization, was used for the study, as the subjects - who were physiotherapists experienced in the management of soft tissue lesions - took the case histories of two simulated cases.

Development of introductory material

Letters of introduction and information sheets were developed for use prior to the conduct of the interviews. In addition, a standard introduction was developed for use immediately prior to each interview to introduce each subject to the procedure employed in the study. The introduction focused on the reasons for undertaking the study and the information sought in the interview, the format of the interview and the instructions to be given to the subject. Examples were provided of previous studies in problem solving involving physiotherapists (Higgs, 1991; 1992) and data derived from think aloud protocols (Haines, 1974; Kassirer and Gorry, 1978).

Pilot work with three physiotherapists suggested that asking the subject simply 'to think aloud' did not result in the subject reporting all their thoughts; discussion after the pilot runs showed that therapists proceeded to take the case histories as in 'normal' clinical practice rather than augmenting it by verbalizing their normally unspoken thoughts. It was decided therefore that more extensive preliminary information was required to ensure that the subject fully understood the requirements of the study. In addition, a sample case history was developed and used to accustom the subject to the procedure.

<u>Development of case material</u>

Two case histories were developed to represent commonly treated soft tissue conditions; these comprised (1) trauma to the soft tissues of the hand and (2) a tear of the lateral ligament of the ankle. The topics were chosen following a search of the relevant literature, discussion with experienced physiotherapists employed in outpatient departments and information provided by the questionnaire conducted in the second part of this study. They were required to fulfil the following criteria:

1. The clinical presentation and history were both suggestive of and consistent with treatment with electrophysical agents.

2. The conditions presented were commonly treated in everyday practice.

3. The condition was one which would provoke consideration of a number of possible treatment plans.

The hand lesion represented an open, acute lesion involving damage to skin and muscle tissue whilst the ankle injury represented a chronic, closed lesion, primarily of ligamentous tissue. Age, sex, social background and the patient's attitude to their condition and it's prior management were also varied between the case histories.

The case history material was derived from discussion with five senior physiotherapists working in general physiotherapy outpatient departments; they had been qualified for between 4 and 14 years and had worked in the management of soft tissue lesions for a mean of six years (range 2 to 9 years). Each was provided with information about the aims of the study and was assured of personal anonymity in any later reports.

Each was asked to describe in full the information they would both elicit and the observations, measurements and tests they would make when presented with a patient suffering from a laceration of the hand or a torn lateral ligament of the ankle. Minimal use was made of probe questions. Written notes were made during the course of the interviews. The notes were written up following the interview and returned to the subject, who confirmed that each report was a correct representation of the interview and a full record of factors each would employ when conducting an examination of a patient.

Two case histories were developed on the basis of the information obtained from the interviews and the literature. Three further experienced physiotherapists acted as independent judges and evaluated the histories; they were asked to comment on the face validity of the cases and the adequacy and relevance of the clinical detail presented. No adjustments were required following their reports.

The following summaries describe the contents of each case history; full details of both case histories are provided in Appendix 11.

Case history I:

A 28 year old male patient sustained a soft tissue lesion of the left hand; he fell onto an outstretched hand whilst at work on a building site, resulting in an open lesion on the palmar aspect. He attended casualty following the injury where the wound was X-rayed, cleaned and sutured. He attended for physiotherapy treatment four days after the injury.

The lesion was clean, though there were signs of inflammation, and both swelling and bruising were present. There was no bony, tendinous, ligamentous or neural involvement; range of movement of the hand was reduced and function impaired. Pain both at rest and on movement posed the main problem.

The patient had no previous history of hand problems, was generally well and physically fit; he was however anxious about his injury and concerned about losing his job.

Case history II:

A 78 year old lady attends for physiotherapy treatment to her ankle four weeks after falling in the street and sustaining an inversion injury to the right ankle. She had a long history of repeated injuries to the joint and had received previous treatment. Immediately following the injury she attended casualty where she was X-rayed, given two sticks and some tubigrip bandage and told to rest the limb.

On arrival at the physiotherapy department she is anxious and wary of using the leg. She lives at home with her husband who is currently performing most daily tasks about the house; her present level of activity is minimal.

The patient is able to take some weight through her foot, walk short distances and is able to climb stairs with help. Balance is poor. She is currently wearing one shoe and one slipper. The foot is swollen and skin condition is poor; palpation reveals 'thickening' of the joint structures and pitting occurs on pressure. No bruising or neural symptoms are evident. Pain is present both on rest and movement and wakes the subject during the night. Both range of movement at the ankle joint and muscle strength in the lower leg are reduced.

In addition, the patient suffers from mild arthritic changes, hypertension and is overweight. She is currently taking diuretics and paracetamol.

These two case histories served as sources of data for the subjects participating in the study.

The reliability and validity of the research design

Few studies have examined the reliability of verbal reports; Ericsson and Simon (1993) note the complexity of this issue and conclude that differences may arise between one problem solving trace and another due to memory of the previous occasions, acquisition of skill in task performance, learning and normal differences in cognitive function.

The reliability of think aloud studies has been addressed in two ways; firstly, test-retest reliability has been examined and secondly, subjects have been asked to provide retrospective reports of the processes used in prior think aloud situations (Ericsson and Simon, 1993; Hagert, 1980a,b). Results of test-retest studies suggest that similar, though not identical, patterns of thinking may occur in situations which are very familiar (Ericsson and Simon, 1993) though there are greater discrepancies when the task is complex or novel (Hagert, 1980a). Comparisons between the concurrent and retrospective data derived on a single occasion suggest that similar aspects were identified on each occasion, though the retrospective trace reported information in a different order from the concurrent trace, was shorter and omitted some of the elements in the concurrent trace (Ericsson and Simon, 1993). However, both Johnson (1962; 1964) and Hagert (1980a,b) note that in parts of their studies reliability was low and suggest that this may be an inherent aspect of normal human problem solving.

The work of Ericsson and Simon (1993) suggests that the more highly practised the skill that is being examined the greater will be the reliability of the trace derived. Kupers and Kassirer (1984) report that in think aloud traces the experimenter can conclude that 'the information reported was actually in the subjects focus of attention at the time' and Ericsson and Simon (1993) state that concurrent verbal reports are reliable traces of the information <u>currently being heeded</u> by a subject. However it is impossible to ensure that all that is in the subject's mind is reported.

A number of tactics may be adopted to increase the reliability of the concurrent verbal trace and the reliability of this study was increased in a number of ways. Subjects were assured of personal anonymity in all reports. They were informed that the researcher was interested in their normal working practices and that there were no right or wrong ways of proceeding. Both of these factors were designed to encourage normal practice and remove any threat associated with 'correctness'. Reliability was also increased through careful selection of subjects; a judgement sample was selected which included both health service personnel and private practitioners and represented clinicians who were designated as both 'effective' and 'very experienced' in the treatment of soft tissue lesions by their peers (further details are presented on page 328).

The validity of research designs used to examine human problem solving are of paramount importance in order to ensure that normal cognitive processes are being tapped (Elstein et al, 1990).

Face, content and construct validity of both the method used in the study and the content of the case histories was examined. The face validity of both were confirmed through discussion and pilot work with experienced clinicians; both the method and the case histories were reported to be comprehensible to the practitioners and the case histories were reported to be sufficiently detailed and credible.

Content validity of the material used to develop the case histories was determined through reference to basic physiotherapy texts, research literature and by deriving the primary data from experienced physiotherapists working currently with soft tissue lesions on a daily basis. The content validity of the final histories were again confirmed by further independent assessors who were experienced clinicians.

The construct validity of the design used has been examined by Ericsson and Simon (1993); they compared it with the most prevalent current model of information processing theory of cognition, first described by Simon and Newell (1973). This model identifies both long term (LTM) and short term memories (STM); material within the STM is immediately accessible for processing and may be heeded whereas that in the long term memory must be retrieved. They note that the processes involved in storage and retrieval may cause some alterations to occur its content. The majority of material from the STM is lost rapidly though a small proportion may be transferred to the LTM. Ericsson and Simon (1993) base their theory of concurrent verbalization (the design used in this study) on this model; a concurrent trace is retrieved from STM and is therefore a verbal encoding of the information in the STM. It therefore reflects the information that the subject is currently heeding. Concurrent verbalisation prevents adulteration of the trace as occurs when retrospective probes are used, which must access the LTM and may therefore result in distortion due to problems with memory or interpretation rather than simple reporting (Ericsson and Simon, 1993).

A number of researchers have suggested that studies of problem solving must address realistic situations in realistic ways. The validity of this study is further increased through matching its requirements to those set out by Barrows and Feltovich (1987), and endorsed by a number of other researchers (Rogoff and Lave, 1984; Perkins and Solomon, 1989; Elstein et al, 1990), for designs which reflect 'real' practice; such designs (1) initially present the clinician with the little information that is characteristic of normal practice; (2) allow the clinician to investigate freely, asking any questions in any sequence; (3) give information about the patient over time, therefore allowing reasoning to occur at each step and (4) do not provide any feedback during the process about 'correctness' of thoughts or actions. The design used in this study fulfilled all these criteria. However, some sacrifice of reality was necessary with respect to the 'patients' used; simulated case histories allowed a number of subjects to address the same clinical problem and thus facilitated comparisons between them. This loss of reality was thought to be acceptable in order to increase the generalizability of the findings.

Thus concurrent verbal traces may be regarded as reliable and valid traces of the information which is currently being heeded by the respondent (Ericsson and Simon, 1993).

II. CONDUCT OF THE STUDY

Design: Simulation studies: process tracing method.

Subjects: Ten physiotherapists, who were regarded as being effective practitioners and experienced in the treatment of soft tissue lesions by their peers, were contacted and invited to participate in the study.

Senior staff in outpatient physiotherapy departments in eight major hospitals within the Southeast Health Region were asked to nominate clinicians in the both the public and private sector whom they considered to be 'very experienced' in the management of soft tissue lesions and whom they believed to be 'the most effective and best practitioners' known to them in this area. 'Very experienced' was defined as three or more years experience in the treatment of such lesions. Each subject contacted was nominated by three or more peers.

Materials:

: information sheets; introductory material;

: case histories

: audio recording equipment

: jotting paper for subject note taking

Procedure: Subjects were approached by letter and invited to participate in the study. Information sheets were included with the letter which informed the subject of the purpose of the study and the basic demands of the study method (Appendix 12).

Following agreement to participate, subjects were contacted by telephone and a mutually convenient location and date determined; all subjects were interviewed at their place of work over a three month period of time. Each was assured of anonymity in all reports. All subjects agreed to the audio-recording of the think aloud interviews.

A standard procedure was used to introduce each subject to the study and methodology employed (see Appendix 13); each subject was provided with further information about the purposes of the study and encouraged to ask any questions. Examples of other studies using similar methods were discussed and practice provided in the methods involved.

Each respondent took the case histories of two simulated patients, which were presented to them in random order. The following statement and request was made to each respondent prior to each study:

'A man (woman) attends for treatment to the hand (ankle)'.

'Please take the history of the presenting problem and develop a plan of immediate physiotherapy treatment. I would like you to 'think aloud', telling me everything you are thinking as you collect information from me'.

The researcher provided responses to the requests for information by the subject, deriving those responses from the case histories. Specific questions only were answered, no response being provided to general questions such as 'what problems do you have?'. Each subject was provided with a single sheet of paper to record information in accordance with normal clinical practice.

A verbatim transcript was made of each case history and checked by an independent assessor for accuracy. The transcripts were subsequently divided into segments defined as a single sentence or phrase which addressed a single issue; examples of the raw data from two transcripts is presented in Appendix 14.

Analysis: analysis of the transcripts addressed two categories; these were content and structure. Content was examined in terms of the hypotheses developed, the cues elicited and the treatments selected. Structure was examined to determine the general strategies used to solve the given problems and the presence of hypothetico-deductive reasoning.

Content: Content analysis was conducted and the process followed was identical to that reported in chapter 4, section II of this thesis. Two independent assessors identified and confirmed the presence of each category within the texts and coding was subsequently performed. Two further assessors checked these codings.

Structure: Script analysis was used to examine the general strategies, or reasoning processes, whilst phrase analysis and content analysis were used to examine specific processes.

Script analysis: The problem solving techniques used by this sample were examined at a gross levels, corresponding linguistically to the paragraph. The methodology used to describe the general problem solving strategies used by these subjects was based on the work of Hobbs (1979), Charolles (1983) and Moskowitz et al (1988). The technique involves examining the script, line by line, and noting the status of the decision or argument at that point. Thematic units, which reflect the cognitive operations being performed at each stage in the problem solving process, are identified.

After examination of the script a set of operations were devised to account for the major reasoning processes of the subjects concerned. The identification and development of these categories were validated through the use of two independent assessors; the text was then categorized. Two further assessors were used to check the reliability of the categorisations.

Content analysis: The text was examined for evidence of hypothetico-deductive reasoning by means of content analysis, using the categories identified by Elstein et al (1978). Two independent assessors were used to identify and confirm the presence of categories within the texts and the text was subsequently coded according to these categories. Two further independent assessors checked these codings.

Results:

1. Subjects:

Nine subjects agreed to participate in the study; the remaining subject who was contacted was unable to participate owing to a change in job which necessitated a move. The male to female ratio was 2:7. Four subjects practised within the National Health Service and five in private practice. All had a minimum of three years clinical experience treating soft tissue lesions (ranged from 4 - 22 years; mean 6.5 years).

2. General information:

Eighteen transcripts were derived, two from each of nine subjects. These are identified as case I, 1H - 9H (hand lesion) and case II, 1A - 9A (ankle lesion). The segments which made up each transcript were numbered. The length of the transcripts varied but were generally longer for case II.

Case I: the number of segments ranged from 144 to 238 (mean: 190)
Case II: the number of segments ranged from 157 to 360 (mean: 226)

3. Content:

Content was examined at the segmental, or phrase, level and the full list of categories identified were as follows:

i. Cue acquisition: information collection which may relate to history, physical examination or tests

ii. Interpretive statements: interpretation of cue information or intention statements

iii. Intention statements: statements such as 'I am going to' or 'I would'; with respect to history taking, examination, treatments

iv. Summary statements: conclusions based on one or more cues and possibly involving their interpretation

v. Hypothesis: problem formulations retrieved from memory

vi. Evaluative statements: evaluations of a cue or number of cues involving an attitudinal element

vii. Beliefs: statements about the beliefs of the respondents

viii. Copy statements: copy of material just reported

ix. Paraphrase statements: a paraphrase of material just reported

x. Recall statements: statements recalling information previously presented in the interview

xi. Miscellaneous statements: eg. OK; right; well; then.

Though the content of the traces was examined with respect to such a variety of elements, these results will address (1) the types of cues elicited, (2) the hypothesis developed and (3) the treatments selected; the remaining categories, though identified at this stage, were used to assist in structure analysis which is reported in the next section.

A general examination of the traces demonstrated that most subjects showed a tendency to divide the task into three sections. The first two sections primarily addressed the assessment of the patient and identification of key problems and the third the development of a treatment plan. The former two sections comprised the following: (1) obtaining information about the history of the condition, observing the state of the lesions and obtaining test results and (2) the physical assessment. Junctures were sometimes emphasised by verbal markers (for example, first juncture - case I, 3H, segment 128; case I, 6H, segment 92; second juncture - case I, 6H, segment 166; case II, 2A, segment 131).

Some overlap, however, occurred between phases; all traces showed some evidence of this between the two assessment phases and the majority (n=6 in each case) commenced some treatment planning during the patient examination. In addition, one respondent in case history I (9H) and two in case II (2A and 6A) returned to data collection during treatment planning.

Cues:

A mean total of 33 cue areas were identified in the transcripts (mean 31 and 35 for cases I and II respectively); information was gathered about current and past symptoms, physical findings, past tests, past treatment, and various aspects of the patient's life style. Each subject elicited between 12 and 23 cue areas (mean 17.5) for case I and between 14 and 24 (mean 19.5) for case II. A full list of cues, ranked according to the number of subjects employing them, is presented in Appendix 15.

The nine transcripts derived for case I demonstrate a degree of similarity in the information (or cue) areas accessed. Eight cues were elicited by all subjects and comprised information about occupation, time since injury, the mechanism of the injury, prior care received, the type of lesion, swelling, range and present medication. A further three areas of information were sought by eight respondents; the age of the patient, hand dominance and hand injured and details about pain. In case II, six cues were derived by all subjects (time since injury, mechanism, swelling, pain, joint range and medication) and four were accessed by eight subjects (age, prior care, gait, present general health). These cues are referred to as 'core cues' in this study.

The core cues elicited in case II closely reflect those in case I, eight being represented in both histories (age, time since injury, mechanism, prior care, swelling, pain, range and medication). The remaining core cues in each case were specific to that injury; in case I these cues consisted of information about (1) the occupation of the patient, (2) the position and appearance of the wound and (3) whether the right or left hand was involved whilst in case II they consisted of information about (1) gait and (2) present general health.

The order in which cue areas were derived varied between subjects though most subjects completed history taking before turning to physical examination. Cues were approached in a variety of ways and included questions about temporal relations, severity, predisposition and complicating factors and need for action. Temporal relations focused on the frequency and duration of symptoms and included questions about the acute or chronic nature of the condition, changes in symptoms since the time of injury and changing patterns of symptoms during 24 hour periods. Questions about severity were primarily directed at the intensity of individual symptoms and the way in which these affected function. Predispositional questions were primarily directed at demonstrating cause-effect links; for example, information was requested about the patient's work and the mechanism of injury in case I with a view to informing the subject about the type of tissues which might be damaged and the possibility of infection.

All respondents in this study sought to access information from other professional experts. Questions were asked about prior care and advice received, the results of X-rays and any prescribed medication. The quality of the expert was sometimes questioned; two respondents noted that X-ray reports were often of dubious value in the early days of an injury, and three questioned the value of the advice or walking aids provided in casualty.

The primary purpose of many questions, often explained directly by the subject or indicated through their interpretation of the information received, was to identify the need for action and for specific therapeutic interventions. Additional questions were directed at identifying the tissue structures involved in the injuries.

Hypotheses:

Few hypotheses were mentioned directly in these transcripts and it was rare for a respondent to be considering more than one or two hypotheses at a time.

In case I the majority of hypotheses involved suggestions about the structures damaged with five respondents identified competing elements. Tissues considered included tendons (n=3), nerves (n=2), fractures (n=2), and 'soft tissues' (as opposed to fractures or joint injuries) (n=2). In addition, a single subject each considered ligament and muscle tears, joint injuries and circulatory damage.

Other hypotheses were reported about presenting signs (n=5), the relationship of the patient's job to the problem (n=3), the presenting condition of the patient (n=2) and his functional level (n=1).

A greater number of hypotheses were identified in case II and these related to (1) the tissues involved; (2) presenting problems; (3) factors predisposing to the injury; (4) factors affecting treatment and (5) the long term consequences of the injury. The following table details these categories.

Table 32. Hypotheses derived in case II

Category	Factors identified and number of subjects
Tissues involved	bony and periosteal damage (3); ligament injury (2); collagen deposition (1); soft tissue injury (1)
Presenting problems	joint laxity (3); stiffness (3); proprioceptive loss (2); general instability (1); muscle weakness (1); swelling (1); bruising (1); inflammation (1); reduced straight leg raise (1)
Predisposing factors	previous ankle injury (2); balance problems (1); pronated foot (1); biomechanical problems (1); defective shoes (1); defective footwear (1)
Factors affecting treatment	osteoporosis (1); general fitness (1); personal motivation (1); slow progression (1)
long term consequences	arthritis (2)

A full list of hypotheses is presented in Appendix 16.

Treatments:

All subjects developed a treatment plan for each condition as requested and each identified treatment objectives; these are listed in tables 33 and 34.

Table 33. Treatment objectives identified for case I (n=9)

TREATMENT OBJECTIVE	NUMBER OF RESPONDENTS
Restore mobility*	9
Reduce swelling*	8
Mobilise scar tissue	3
Reduce inflammation*	3
Back to work	2
Reduce adhesions*	1
Prevent tissue shortening	1
Reduce pain*	1
Resolve haematoma	1

* - denoted objectives common to cases I and II

Table 34. Treatment objectives identified for case II (n=9)

TREATMENT OBJECTIVE	NUMBER OF RESPONDENTS
Reduce swelling*	7
Reduce pain*	6
Increase general function/mobility*	6
Re-educate gait	5
Mobilize ankle joint	4
Reduce adhesions*	3
Re-educate proprioception	2
Increase confidence	2
Reduce inflammation*	1

* - denoted objectives common to cases I and II

Nine objectives were explicitly identified in each case; in case I subjects reported between 2 and 4 (mean 3.2) and in case two between 3 and 6 (mean

3.3). A number of objectives were common to both cases and are denoted in the tables by a *. Increasing or maintaining mobility and the reduction of swelling are the most common objectives of these subjects for case I, whilst the reduction of swelling and pain and an increase in function and mobility head the list for case II. Thus, in both cases reduction in swelling and increase in mobility rank as high priorities.

A number of additional objectives were indicated indirectly through the choice of and explanations about treatments; however these are not presented here as it was not possible to identify them with certainty.

Subjects reported the need to use between four and six forms of treatment to fulfil the objectives for case I; all planned to use active exercise as part of their programme and eight planned to use electrophysical agents and elevation. Support, such as the use of a sling, and advice were both planned by five subjects each. A total of 14 treatment options were identified for case II, with subjects selecting between 3 and 8. Though all subjects planned to employ electrotherapy in the treatment of this lesion, a greater range of other options were selected than in case I; two thirds of the subjects selected active exercise (n=7), elevation (n=6) and advice (n=6) as adjunct treatments to electrotherapy. Appendix 17 contains full details of all treatments identified.

In both cases, subjects identified the types of electrophysical agents they were most likely to select; in addition, some noted alternatives and treatments they considered specifically not appropriate. Selection of electrophysical agent varied; in case I, five stated that they would choose pulsed shortwave diathermy (PSWD), three selected ultrasound (US) and two laser. One subject elected to use both laser and US and one suggested use of PSWD over the lesion and US for the surrounding tissue. One subject reported that it was unlikely that she would use any electrophysical agents.

Three subjects suggested alternative forms of electrotherapy which they might use but were less happy with; these were US (n = 2) and PSWD (n = 1). However, 5 respondents also suggested that there were certain agents which they would definitely not use; these were again US (n = 4) and PSWD (n = 1). Three suggested that ultrasound and pulsed shortwave diathermy were interchangeable but selected one or other on the basis of practical considerations. Reasons given for not using PSWD included the perception that the agent was ineffective with respect to reducing swelling, the need for physical contact between the applicator and the wound and the inappropriate size of the applicator; reasons identified for not selecting US included the need for a non-contact technique as the wound was open, the belief that the agent was ineffective for the presenting lesion and for softening scar tissue and that it was inappropriate in the early stages of response to injury.

In case II, five stated that they would choose pulsed shortwave diathermy, five selected ultrasound and two interferential stimulation (IF). Two subjects elected to use both PSWD and US and another to use PSWD and IF. One subject suggested US as an alternative to PSWD and one IF as an alternative to PSWD and US. Two subjects stated that they would not use US because of the size of the area, local tenderness over the bone and the possibility that it might exacerbate the problem.

A variety of reasons was given by the subjects for using each agent, and these are shown in table 35. They included both the physiological effects they wished to produce in the tissues and practical issues concerning the application of each form of electrotherapy.

Table 35. Reasons identified for selection of electrophysical agents (n=9)

	PSWD: no. of subjects	US: no. of subjects	Laser: no. of subjects
PHYSIOLOGICAL EFFECTS			
Reduce swelling	7	3	-
Reduce bruising	2	-	-
Decrease pain	2	3	1
Decease scar formation	-	2	2
Increase circulation	2	-	-
Increase rate of healing	1	4	2
PRACTICAL ISSUES			
Size of lesion	5	3	-
Method of application	5	1	1

In both case studies those who gave an indication of the type of dosage they planned to use reported the need for low intensity treatment parameters for all three agents.

4. Structure

Structure was examined in terms of general strategies and specific tactics.

General strategies:

General problem solving techniques used by this group were examined by looking at (1) the types of operations conducted and (2) the sequencing of these. Script analysis identified thematic units at the equivalent of the paragraph level within texts and corresponded to the following operations:

i. Collect: collection of information with respect to history, physical finding and the test results.

ii. Hypothesize: develop, identify or discuss hypotheses

iii. Interpret: interpretation of the information received, based on prior knowledge

iv. Explain: justify or explain interpretations or plans on the basis of prior knowledge

v. Review: review facts, hypothesis or process

vi. Conclude: draw conclusions based on information received

vii. Plan: plan treatment

Figure 7a provides a sample from a transcript which has been categorised in this way.

Figure 7. Script analysis derived from case II; 1A

Operation	Segment nos	Contents
Collect	168-184	Leg length; muscle wasting; gait; balance
Conclude	185-188	Biomechanical problem; gait problems
Interpret	189-193	No gross muscle wasting therefore improvement expected
Hypothesise	194-197	OA changes if gait not corrected
Collect	198-221	Joint range; swelling; pain;
Review	222-228	Frightened; elderly; overweight; inactive; biomechanical problem; relying on husband
Conclude	229-231	Confidence, swelling, movement problems
Plan	232-233	Treatment: using (mechanical) pump
Explain	234-238	Reduce swelling
Plan	239-241	Elevation; massage
Explain	242-244	Swelling; confidence

Full analysis of the remaining traces are found in Appendix 18.

The number of thematic units identified varied between 22 and 43 (mean 34) for case I and between 21 and 55 (mean 41) for case II. Unit length varied from one (for example, 2H, segment 10) to 39 segments (1A, segments 23-61). In addition, a number of transcripts contained method segments, which referred to practical issues such as positioning of the patient.

Seven types of operations (listed above) were used by these clinicians; it was found that information collection dominated the early part of each transcript and provided the basic information upon which interpretation and later treatment planning could be based. Each trace commenced with a collection phase and these phases continued to appear throughout the assessment section of the transcript; each varied in length from one to 39 segments.

Information about individual topics was predominantly gathered sequentially, particularly when 'objective' information was being obtained during history taking and the physical assessment. However, cyclic information gathering appeared elsewhere, especially in case II. An example of linear information gathering, derived from case I, is shown in figure 8 whilst Appendix 19 provides an example of a trace which contains both cyclic and linear information collection.

Figure 8. Evidence of sequential information gathering: case I, 6H

INFORMATION OBTAINED	SEGMENT NUMBERS
Neural symptoms	66, 67
Present health / medical history	75, 76, 78
Medication	82, 84-86, 88
Temporal patterns	90
Skin colour	134
Swelling	140-142
Bruising	144
Skin condition	146
Associated problems	147, 148
Strength	164, 166

Cyclic information gathering was introduced mainly when the area was 'subjective' in nature, for example pain, or when the physical examination was used to confirm the historical narrative of the patient. In some traces a topic, such as pain experienced or range of movement, was introduced firstly as part of the history taking and then again as part of the physical assessment.

Units addressing interpretation of cues and/or explanations normally appeared early in each trace, though commencement varied from segment 7 (4A) to 70 (1A); the mean point of onset was segment 20 in case I and 14 in case II. Interpretative and explanatory units varied in length from 1-23 and 1-18 segments respectively. Explanation units provided a rationale for information gathering and were therefore more abstract in nature than the interpretative units. All subjects employed both types of operation, though there was a tendency for some to provide greater levels of explanation than others.

As noted above, the majority of subjects reported hypotheses during this study (case I: n = 7; case II: n = 9). These units focused on the types of tissue injured, clinical and functional problems the patient might have as a result of the lesion, predisposing factors leading to the injury or factors which might affect return to normal. Units concerned with hypotheses were generally short in length (1-8 segments).

A number of operational units addressed the conclusions that were drawn by these subjects about the problems the patient was experiencing, treatment priorities and the likely outcome; reviews units were infrequent but when present summarised previous information received or treatments selected.

The sequencing of operational units was examined and found to be similar in all transcripts; the most common pattern observed in the early part of the transcripts consisted of cycling through the phases of data collection and data interpretation, the latter being sometimes followed or preceded by a phase of explanation. On some occasions interpretation was replaced completely by explanation. The following extract from case II, 3A demonstrates this pattern.

Figure 9. Case II. 3A. Operation patterning in the initial phases of data collection.

Operation	Segment number	Contents
Collect	1-11	Time since injury; main problem; mechanism of injury; pain; swelling; bruising
Interpret	12-26	Chronicity; severity; structures
Collect	27-33	Previous ankle injuries and treatment
Interpret	34-51	Frequency of injury; joint laxity; chronicity; efficacy of care
Collect	52-60	Prior treatment
Explain	62-67	Severity of problem; reports of prior tests; present interventions
Collect	68-79	Pain; R/L leg; weight bearing

This pattern was, on occasions, interspaced with smaller units which identified hypotheses, reviewed previous information or drew conclusions (see figure 7).

During treatment planning, subjects cycled through phases of planning and explanation (see figure 7); the number of cycles varied between five and nine, each section commencing with a planning phase. These sections were much shorter than the patient examination sections, averaging 49 segments for case I and 44 for case II. Almost no problem solving occurred during these phases though a single subject readdressed the selection of electrotherapy.

In the majority of traces, operations involving treatment planning commenced approximately half way through each script and therefore prior to the main planning section; however, one subject in case I began planning at segment 26 (of 170) and two vocalised no plans at all until the full examination was completed. A similar pattern appears in case II; one subject commenced planning treatment at segment 43 (of 172) whilst two left all planning until the treatment phase.

Specific tactics:

Evidence of hypothetico-deductive (or backward) reasoning was sought at segmental level through the use of content analysis and the categories defined by Elstein et al (1978), which are as follows:

i. Cue acquisition: information is obtained by the clinician; history, examination, tests.

ii. Hypothesis generation: alternative problem formulations are retrieved from long term memory

iii. Cue interpretation: cues are interpreted in the light of hypothesis

iv. Hypothesis evaluation: data weighed and combined to determine whether hypothesis can be accepted or rejected.

All four categories were identified within the texts; figure 10 provides an example from this study.

Figure 10. Case 1A; an example of backward problem solving*

Cue acquisition:

1. is she walking unaided?
2. and when did she do it?
3. and what was she doing?
4. on a stone, a loose paving?
5. is she going to sue the council for it?
6. OK,
7. so she's walking unaided
8. what age is she?
9. uh, right
10. what kind of shoes was she wearing at the time?
11. is she a sort of fit 78 year old or ...?
12. very doddery, unstable?
13. right
14. overweight?

Hypothesis formation:

21. she may have a balance problem

Cue acquisition:

34. is she loosing her balance when she does that?
35. is it always on the pavement

36. or is it sometimes at home?
37. is she blacking out?
38. has she got high blood pressure?
39. at what sort of level?
40. what's her palpitation rate, do we know?

Cue interpretation:

69. there aren't any major organic problems going on

Hypothesis evaluation:

70. so she's not got ataxic
71. or a balance problem

* responses to questions have been omitted to increase clarity

Cue acquisition: This process was identified in all 18 transcripts by the researcher and two independent assessors; no discrepancies between assessors was noted during this process. Further details of the pattern of cue acquisition and the type of cues accessed has already been provided.

Cue acquisition both provided the basis upon which hypotheses were developed and information which led to hypothesis evaluation. The majority of information units in these traces, however, did not lead directly to hypothesis formation and were not overtly hypothesis led.

Hypotheses generation:

Hypotheses were generated in 16 of the 18 traces and varied in number from one to nine. Following instructions from the researcher and two independent assessors that only overt hypotheses would be examined, full agreement was reached about those discussed previously in this section (see Appendix 16 for a full list of the hypotheses generated).

In case I, two respondents mentioned no hypothesis, and the remaining seven identified between one and eight (mean = 2.9). The majority of hypotheses were located in the first half of each trace. A slightly larger number were generated in case II (range = 1-9; mean = 4.3). The onset of hypothesis generation was often later in case II (only 3 subjects generating their first hypothesis in the first quarter of the transcript) than case I (5 subjects generating their first hypothesis in the first quarter of the transcript). The following table identifies these points of onset.

Table 36. Onset of hypothesis generation in each transcript

subject	1	2	3	4	5	6	7	8	9
case I; hand	1/4	-	1/4	-	1/4	3/4	2/4	1/4	1/4
case II: leg	1/4	1/4	2/4	1/4	2/4	2/4	3/4	2/4	2/4

Key: 1/4 = first quarter of transcript etc.

Hypotheses were generated in response to individual cues or groups of cues and were sometimes based on very small amounts of information. For example, two subjects (1H; 5H) formulated competing hypotheses about the tissue structures involved in the injury immediately following information about the mechanism of the injury; both sets of hypotheses were completed by clause 10 of the traces; this pattern is repeated in trace 6A, case II, though the hypotheses were generated later in the trace (6A: segments 48;

49). Trace 8H demonstrates hypothesis generation with respect to tissues injured following the acquisition of a <u>group</u> of cues, these being about body build, hand and lesion position, the presence of slings or bandages and the time and source of referral. In addition, trace 6A incorporates the retrospective reporting of a prior hypothesis about the presence of a fracture, the subject having already inquired about X-ray findings.

Though many hypotheses were subsequently evaluated, not all led to further action as some remained unaddressed (see Appendix 16). For example, one subject (trace 6H) hypothesized that increased activity would occur when stitches were removed; another (trace 1A) that arthritic changes might develop in due course and still others (traces 2A; 9A) that prior injury had predisposed the patient in case II to the present condition. Such hypotheses could not be tested at the stage of assessment.

<u>Cue interpretation</u>:

In this study interpretation of cues largely equated with the interpretive phases previously described. Individual segments were coded with respect to this category and agreement between independent assessors was 96%; following discussion the remaining segments were allocated to either this category or the explanatory groupings discussed above. The following example, shown in figure 11 demonstrates cue interpretation.

Figure 11. <u>Case 5H. Cue interpretation</u>

25. and what colour?
*: it's red ... slightly hot
26. no blue tips?
*: no blue tips, no
27. OK ...
28. well, again I would be extremely wary if it was looking a bad colour
29. bloodwise
30. and suspect fractures
31. and would send him off immediately for X-rays ...
32. if the colour looked normal -
33. I'd expect it to be swollen if he hurt it badly
34. and if the colour looked normal and he'd got good circulation again
35. it might be soft tissue ....

<u>Hypothesis evaluation</u>:

Evidence was found in the traces to show that cue acquisition and interpretation led to both confirmation and disconfirmation of hypotheses; the following example demonstrates cue confirmation.

Figure 12. <u>Case 3H: Confirmation of hypothesis</u>

27. so again how bad the injury was initially ..
28. it's obviously quite nasty ..
29. probably stop him working for a while ..
....
97. are you working at the moment?
*: no .. I can't work
98. what do you do .. for work?
*: I'm a construction worker
....
101. then he's off work ..

In this example confirmation was sought at a later point (S=97) and not immediately following the development of the hypothesis (S=29); this pattern was repeated in a number of other traces (eg. 6H; 4A).

Disconfirmation of hypotheses was also preformed by these subjects; the following example from case 1H demonstrates the use of selective cue acquisition and interpretation with final disconfirmation (S=11) of the hypothesis (S=5). An alternative hypothesis is then formulated (S=13).

Figure 13. Case 1H. Disconfirmation of hypothesis

4: so .... if he fell on an outstretched hand he would have been tense ..
5. a fracture possibly ...
6. if he'd sort of rolled onto it, it is more likely to be soft tissue injury ....
7. he has seen a doctor?
*: yes , he went to casualty.
8. he went to casualty?
9. so has he had an X-ray?
*: he had an X-ray ...
10. any fractures?
*: there are no fractures
11. OK ... well, so I know already that it is not a fracture ....
12. it's a soft tissue injury ...
13. probably a contusion or ligament injury ...

Subjects gained most information used in hypothesis evaluation directly from the 'patient'; for example, information about skin colour and circulation were requested and interpreted directly in order to establish a hypothesis, such as the presence of a fracture (see figure 11 above and trace 5A; S 25-34). However confirmation or disconfirmation of hypotheses could involved the use of information derived from other professionals; in the above example this took the form of the results of an X-ray taken at a casualty department. Hypotheses tendered about the presence of tendon lesions in case I were also disconfirmed through questioning about the results of tests (for example, 8H, segment 68).

In some cases no direct evaluation of hypotheses appears to take place, though the subject continues to behave as though it has; for example, in trace 7H hypotheses are developed about possible median nerve damage (segments 108-110; 113). Though cues are elicited about the presence of neural symptoms, no overt conclusions are drawn. However, further questioning about the ability of the patient to perform active movements implies covert rejection of the hypothesis.

Section III. Chapter 4.

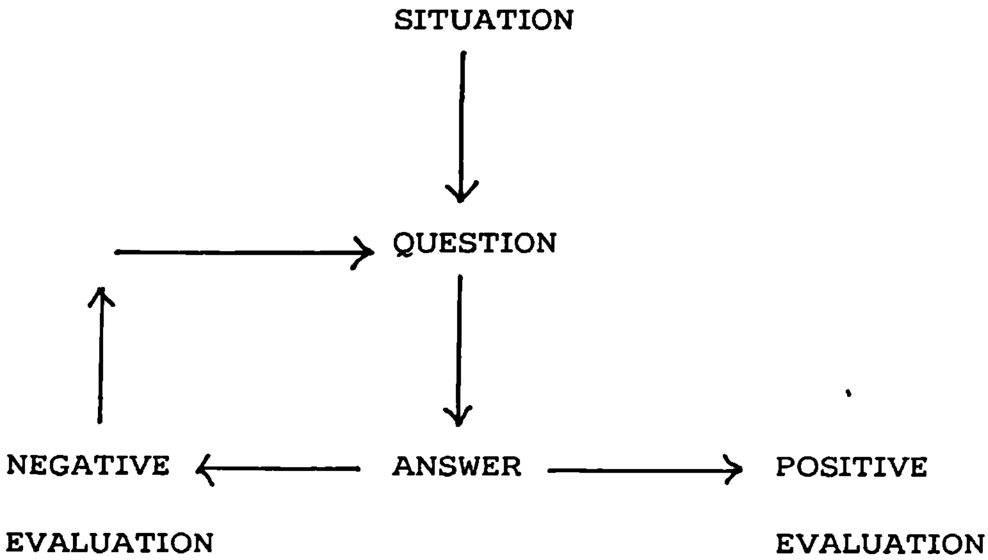
CLINICAL PROBLEM SOLVING IN PHYSIOTHERAPY: DISCUSSION

This study provides evidence to show that, though physiotherapists generally problem solve in a way which is similar to that identified in many other studies in a wide variety of spheres, the operations used differ from those which medical practitioners employ in diagnostic reasoning. It also shows that the specific tactics used are of more than one type, a finding contrary to much present evidence but in line with some recent hypotheses (Patel and Groen, 1986; Elstein et al, 1990). Finally it demonstrates that, though the management decisions made by the respondents are generally similar, some disagreement is evident with respect to the selection of electrophysical treatments.

Four hypotheses underlay this investigation and each will now be examined in turn.

The first hypothesis stated that 'experienced physiotherapists use the same gross problem solving strategies to solve familiar problems as other professional people'. Physiotherapists in this study employed a similar basic pattern of problem solving as those identified by Hoey (1983; 1986) in his work on clause relations within texts, a pattern Hoey has suggested may underpin much general reasoning. The following diagram demonstrates this pattern, which, he suggests, reflects the reasoning processes in a number of contexts including problem-answer (Hoey, 1983; Jordan, 1984), question-answer (Collier-Wright, 1984) and hypothetical-real texts (Williames, 1984)

Figure 14. <u>Problem solving model developed by Hoey (1988)</u>



Thus a problem (in this case an issue pertaining to the patient, such as pain) is identified and questions are asked to clarify that problem. When the information is received it is evaluated in the light of prior information from the patient and prior knowledge stored in the long term memory and an answer developed. A positive evaluation may lead directly to the development of a plan (in this case, further areas of investigation or treatment) or further questioning, whilst a negative evaluation generally leads to further questioning. The process may be repeated for a large number of 'problems' and will finally lead, in this case, to the development of a treatment plan.

Despite these general similarities, differences between the reasoning operations used by physiotherapists and other medical practitioners may exist. However, care is needed when comparing studies which examine diagnosis with studies which examine patient management, with or without a diagnosis, as the objective of the evaluation may be slightly different and the operations used <u>may</u> therefore differ. Physiotherapy assessment is normally of the latter type with most practitioners identifying presenting problems (which may be at the levels of impairment, disability and handicap) rather than attempting to select a diagnosis (Jones, 1992a).

Moskowitz and colleagues (1988) are one of the few groups of researchers who have investigated patient management by medical practitioners; they examined the problem solving strategies used by pulmonologists and identified the following operations:

- review: facts, hypotheses, prerequisites or plan-steps
- consider: hypothesise
- compare: compare quantities
- problem: define the alternative actions
- choose: make a selection
- insert: add a step to the plan

When this model was applied to the traces derived from the present sample it was found that it did not account for all the operations occurring and included operations that occurred rarely and for this reason it became necessary to develop the set of operations which have been presented in the results.

The differences between the two sets of traces may be partly due to the methodology used and partly due to the nature of the task. Moskowitz et al (1988) presented their subjects with written segments of information about a complex case, asking them to identify and select tests and choose whether to prescribe a particular toxic drug; they were asked to think aloud as they received each element. This was followed by retrospective exploration of aspects of the reasoning process; the task was to make a clinical management decision under circumstances in which diagnosis was likely to be uncertain. Only a portion of the transcripts was analyzed, being that in which clinicians constructed a management plan.

These factors appear to have led to a greater use of the review operation, a larger number of hypotheses being developed and the use of a 'choose' operation in the work of these researchers. No information collection and little interpretation or explanation appears to have occurred, for reasons which may relate to the 'given' nature of the data used. In the present study the data derived was self-selected, which may partly account for the presence of few 'choose' operations, as identified by Moskowitz et al (1988). In contrast to the present study, where the initial stages of the traces cycled between collect and interpret/explain operations, those of Moskowitz et al (1988) cycled between review and consider (or hypothesize) operations. The information available about the latter study suggests that the subjects have attempted to develop a diagnosis despite the nature of the request made to them.

The first hypothesis is therefore accepted but with reservations. Evidence from this study suggests that the general problem solving strategies used by this group tend to reflect basic problem solving models postulated in the literature, though medical staff and physiotherapists do not necessarily employ the same operations to achieve their ends.

The second hypothesis stated that 'experienced physiotherapists use hypothetico-deductive methods to solve familiar clinical problems'. Research reported to date which examines problem solving by physiotherapists has suggested that they make use of the hypothetico-deductive method of reasoning to solve problems. This appears to run counter to some recent theory which suggests that this form of reasoning is a weak method which uses a general 'generate and test' heuristic (Feltovich and Barrows, 1984). A number of researchers have suggested that it tends to characterise the problem solving processes of novice practitioners or experts when dealing with novel or ill-defined situations (Newell, 1973; Groen and Patel, 1985).

Detailed examination of the specific strategies used by these subjects revealed that, though the majority used hypothetico-deductive methods of reasoning as they took the history of a common case, it was not the only method employed and may not have been the predominant one. These subjects clearly employed other methods which may include propositional reasoning, heuristic reasoning, semantic differentiation and pattern matching.

Those researchers who have identified hypothetico-deductive reasoning in their studies of clinical reasoning have suggested that it is primarily a hypothesis driven process and that the majority of cues derived will therefore be similarly driven. In this study this was not the case; few cues showed <u>overt</u> evidence of being hypothesis led. Some might argue that in 'think aloud' studies it is not possible to be certain that all thoughts are verbalised and that <u>covert</u> hypothesis may therefore have existed to guide the assessment process, a view postulated by Barrows and Tamblyn (1980). However, Ericsson and Simon (1993) state that concurrent verbalisation reliably records the information currently heeded in the short term, conscious memory, and it is likely therefore that the subjects were predominantly following a forward reasoning process, such as pattern matching.

Hypothetico-deductive reasoning normally involves the evaluation of a number of competing hypotheses resulting in the subject, however briefly, following different avenues of investigation. Generally there was little evidence of this process occurring in these traces, though it arose when some subjects developed and evaluated competing hypotheses about the structures involved in the injury. This again suggests that the problem solving tactics being used are primarily of a forward nature, though some backward reasoning is evident.

The number and type of hypotheses and time of onset have been examined in many studies and it has been suggested that hypothesis generation normally occurs early in the problem solving process and serves to limit the size of the search for a solution (Elstein et al, 1978). Elstein et al (1978) concluded (1) that clinicians begin hypotheses formulation early in their encounter with the patient (by 10% of the way through the assessment) and (2) that multiple tentative hypotheses were typical in the early part of the problem solving process. Others such as Barrows and Tamblyn (1980), Barrows and Feltovich (1987), Payton (1985) and Jones (1992) have supported this view.

In this study, however, the first identifiable hypothesis did not always occur so early and the total number was small. In case I, no hypotheses were identified in two traces and two further subjects delayed the onset of hypothesis generation until half way through the trace or later. In case II, two thirds of the subjects delayed onset until half way through the trace or later. Thus a considerable amount of information was derived prior to the overt development of any hypotheses, again suggesting the possibility of forward reasoning.

Few hypotheses were generated, especially when compared to the work of Kassirer and Gorry (1978) and Jones (1992b). However, not all researchers categorise and identify hypotheses in the same way, thus leading to some difficulties in interpretation of and comparison between studies. Elstein et al (1978) and Barrows and Tamblyn (1980) examined the process of diagnosis and therefore considered only hypotheses concerning possible solutions; they noted that the total number of hypotheses developed varied up to seven. In contrast, Kassirer and Gorry (1978) asked medical practitioners to 'take the history of the present illness' of a simulated case with a view to establishing a diagnosis and identified between 14 and 37 hypotheses in the traces derived, with a maximum of between four and eleven active at any one time.

Both Payton (1985) and Jones (1992a) have addressed hypothesis development with respect to physiotherapists. Payton (1985) replicated the work of Elstein et al (1978) with ten therapists and identified the development of 34 'problem-hypotheses', each therapist identifying between one and five factors. It is, however, unclear from the study whether these hypotheses refer to the identification of the patient's main problems or some other factors. As in the study of Elstein et al (1978), no mention is made of the development of more general hypotheses during the course of the study and it is therefore impossible to compare this work to the results of the present study or that of other workers. In this study, all hypotheses were noted, and it was found that subjects generated between one and nine hypotheses, with a mean of 3.6, considerably fewer than in other studies.

Jones (1992a) proposed a theoretical model to account for the types of hypotheses derived by physiotherapists (see page 293 and following).

The types of hypotheses addressed in this study varied greatly but many fell within the categories suggested by Jones (1992a). Those addressing the type of tissue injured fall within his first category, 'the source of symptoms or dysfunction'; others could be assigned to the 'contributing factors' category. A few hypotheses, dealing with factors likely to affect long term recovery, might be assigned to the 'prognosis' category, though the definition provided by Jones (1992a) suggests that he sees this category as one which focuses on the estimation by the therapists of outcome of therapy intervention and time to recovery. No hypotheses were identified which fell into Jones's remaining two categories of (1) precautions and contraindications to examination and treatment and (2) management. Nevertheless, these areas were addressed by all respondents but <u>not</u> through the use of identifiable hypotheses.

In addition, these subjects hypothesised about the type of symptoms they would expect to see and would therefore assess and the problems the patient was likely to be experiencing; this reflected the results of Payton (1985) who noted that some of his subjects hypothesised in advance about the problems they were likely to encounter with the patient in question. It is possible in the present study that these categories were also partly a result of the study design; for example, one subject hypothesised that the patient might be wearing a bandage and another that the limb might be held in a dependent position, both points which would have been self evident in a life situation.

Though it is beyond the scope of this thesis to examine other types of problem solving used by these subjects in detail, examples from the traces are suggestive of their presence. Propositional reasoning, described in chapter 1 of this Section, is deductive in nature and is characterised by the presence of causal and conditional rules; an antecedent and consequent are identified. Such devices may be identified in many of these traces. For example, 'if he'd sort of rolled onto it, it is more likely to be a soft tissue injury' (1H, segment 6) and 'if she can't weight bear properly then she isn't likely to be getting around' (4A, segment 97). Heuristics involve the use of general purpose rules-of-thumb; examples include 'you couldn't use a contact method' (1H, segment 146) and 'I would hope that his healing properties were good at that age' (2H; 60, 61).

Pattern matching is a much more difficult reasoning method to identify and Groen and Patel (1985) highlight the little that is known about it. It is believed to be based upon the effective use of highly developed knowledge bases which are thought to be characteristic of experts. A number of studies such as those by Norman and colleagues (1985; 1988) and Bordage and Zacks (1984) have recently started to investigate the organisation of knowledge in novice and experienced practitioners, though few conclusions have as yet been drawn. Studies are needed to examine these aspects in experienced physiotherapists to identify the content and characteristics of their knowledge and examine their use of these bases in assessment and treatment selection. Such an understanding would provide a basis for the development of educational practice which will foster student reasoning skills and provide information to increase the efficiency and efficacy of practising clinicians.

The second hypothesis was therefore rejected; though hypothetico-deductive reasoning was identified in 16 of the 18 traces, these subjects also make use of other types of reasoning. Further studies are required to examine these processes in detail.

The third hypothesis examined in this study stated that 'the problem solving strategies used by experienced physiotherapists to examine two common conditions are similar'. This hypothesis was confirmed by the results presented in the previous chapter and discussed above. In both cases the subjects used the same reasoning processes to solve the clinical problems presented to them. All subjects followed the reasoning pattern identified by Hoey (1986) and all used the same operations identified through script analysis in this study to obtain and evaluate information for both cases. In addition 16 of the 18 traces showed signs of the use of some hypothetico-deductive reasoning, as evidenced by the presence of hypotheses and their evaluation.

Few differences between the two cases were identified; those that were noted included the greater length of traces and the slightly greater use of cyclic information gathering in the second clinical case involving an ankle injury. Neither of these differences, however, affected the nature of the underlying reasoning processes used.

A number of factors may have contributed to the similarities in process. Both cases were representative of common conditions seen in general clinical practice and both addressed uncomplicated soft tissue lesions. Nevertheless the similarities seen here are strongly supported by the evidence presented and it is therefore likely that therapists use the same processes in many other situations which are familiar and lack complicating and unusual features. Further studies are, however, needed to confirm this hypothesis.

Finally the fourth hypothesis examined stated that 'experienced physiotherapists make similar clinical decisions for each case study'. Subjects made decisions about the main problems faced by the patient and the most appropriate types of treatment to use. There was a considerable level of agreement between subjects about their management objectives and the general forms of treatment to be selected. In addition all but one subject elected to use one or more forms of electrotherapy for these two cases. There was, however, some uncertainty and disagreement about the types of electrophysical treatment which were most appropriate.

All subjects identified similar treatment objectives for case I; as reported in the results all identified the need to restore mobility and all but one the need to reduce swelling. The remaining objectives were identified by a third or less of the subjects, suggesting that the first two were the core aims of treatment common to all therapists for this case. In case II there was greater diversity; two thirds or more of the subjects, however, identified the need to reduce swelling and pain and increase function.

Subjects also demonstrated similarities when selecting general treatments. Almost all subjects identified the same three treatments for case I, whilst two thirds or more identified four treatments in case II. Again, almost all subjects elected to use electrotherapy for both of these cases, though the agents selected varied. The electrophysical treatments predominantly chosen made use of non-thermal electromagnetic and sound energy; ultrasound and pulsed shortwave diathermy were most commonly selected with laser and interferential stimulation being regarded as possible options by a small number.

The reasons for disagreement over the selection of individual types of electrophysical agents are unclear, but an underlying lack of clarity about the effects and efficacy of these agents may be the cause. Many subjects in the early stages of the development of the study to investigate usage, presented in section II of this thesis, intimated that their understanding of the principles, effects and benefits of electrophysical treatments was both scant and confused. There is some evidence in the current study which confirms this; for example, one subject reported that use of ultrasound was not appropriate in early stage lesions and another reported confusion over dosages. This suggests that the knowledge base of experienced clinicians about electrophysical agents is poorly informed and structured, relying primarily on heuristic principles. Such a situation could lead to the confusion seen in this study. The greater levels of uniformity and confidence expressed with respect to the assessment and the remaining treatment elements suggests that this problem does not exist in those areas.

Section I of this thesis reviewed the information currently available to practitioners about the effects and efficacy of a number of electrophysical agents. This has demonstrated both the knowledge which is available and the gaps which still need to be addressed and shows that therapists work within an environment characterized by uncertainty with respect to this form of treatment. Further research, both at the basic science and clinical levels, is therefore needed to reduce these deficits. In addition, this study highlights the need for physiotherapists of all grades to develop as full and coherent an understanding of the effects of electrophysical agents as is presently possible, in order to facilitate treatment selection and the use of strong methods of reasoning.

The last hypothesis is therefore accepted with respect to most of the decisions made by these subjects, though not with respect to the use of electrotherapy. In order to examine this aspect further there is a need for studies to examine the content and structure of the knowledge base held by physiotherapists of different levels of experience about electrophysical agents.

In conclusion, Lesgold et al (1981) and Patel and Groen (1986) argue that the problem solving techniques of expert practitioners involve the use of rapid recognition skills, which results in interaction between lower and higher levels of representation and leads to a combination of hypothetico-deductive and pattern recognition methods. Lemieux and Bordage (1992) reiterate this view, noting that subjects may vary in the processes they use to solve a single problem and often combine a number of methods, forward, backward and vertical. Hypothetico-deductive reasoning has been shown to be present in the transcripts examined in this study and, though no concrete evidence has been identified to confirm the presence of other procedures in this group, there are indicators that they exist.

CONCLUSION

CONCLUSION

This thesis has examined issues about the nature, use and selection of ultrasound, shortwave diathermy and laser by physiotherapists who are involved in the management of soft tissue lesions. The work is part of a wider inquiry into the clinical efficacy of many aspects of physiotherapy, including electrotherapy.

It has shown that clinicians using electrophysical agents are compelled to work under conditions of uncertainty. An in-depth examination of the literature about these agents, which has provided a substantial basis upon which research can be based, has revealed that currently information is patchy and sometimes contradictory, a situation demanding further investigation.

Patterns of use of electrophysical agents are changing with time. In the present study the majority of clinicians reported using all three agents in the management of soft tissue lesions, often interchangeably. They reported that many of the factors influencing their decisions were related to the practical application of treatments, and that their knowledge, often reported in terms of a lack of information, affected selection.

When solving a familiar clinical problem under conditions of uncertainty, the physiotherapists in this study used general reasoning processes which were similar to those identified in the literature as in use in many common situations. However, an examination of the specific strategies used suggests that they employ a combination of different types of reasoning; although not investigated in detail, subjects appeared to use forward reasoning methods in addition to the backward methods implicit in hypothetico-deductive thought. This contrasts with previous studies involving physiotherapists which have suggested that hypothetico-deductive reasoning is the main technique used.

Further work is needed to expand this area of research. Firstly, there is a need to investigate the forward reasoning processes used by therapists. The presence of propositional reasoning, the use of heuristics and pattern matching and the structural semantics of the text should be examined. An important approach to this is through the examination of the content and structure of the knowledge base held by clinicians about electrophysical agents and their effects. This will increase understanding of the factors affecting selection and improve decision making in both experienced and inexperienced therapists. Secondly, further research in the area of clinical problem solving should be undertaken with less experienced subjects and in other physiotherapy fields of practice to examine the similarities and differences. Finally, it is essential that the knowledge basis of clinicians is continually revised and expanded as new information about efficacy and safety of electrotherapy is reported.

Such research can inform the development of aids to decision making, thus facilitating the learning of student and novice practitioners and the clinical performance of all physiotherapists as they seek to make best use of the therapeutic techniques available to them.

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APPENDICES

APPENDIX 1.

Information sheet: phase 1

CLINICAL USE OF ELECTROPHYSICAL AGENTS

Physiotherapists have been using electrotherapy for many years to treat a wide variety of conditions; agents have included long wave, shortwave and microwave diathermy, faradic currents, direct currents, infrared and ultraviolet radiation. More recently, ultrasound, TENS, new forms of stimulating currents and laser have joined the repetoir.

Research is needed to find out what the benefits are of each of these agents; there is, however, a limit to the time and resources available for this purpose. A number of recent surveys have looked at the types of equipment that are held by clinical departments around the country but this doesn't necessarily tell us what is being used (Ide and Partridge, 1986; 1989). One or two other studies have also looked at the way single items of equipment such as ultrasound have been used (ter Haar et al, 1987) but informal reports from clinicians suggest that practice may be changing with the introduction of new agents and clinical techniques.

We would therefore like to find out what clinicians have available to them, what they are currently using in clinical practice and how they are using the different forms of treatment. This information will also help us to focus our research on the most important areas. In addition it will provide information which will help us to adapt and rationalise the electrotherapy courses we run at the undergraduate level and develop useful postgraduate educational programmes to plug any gaps we may find.

We would like to start by asking you to tell us about the use you make of electrotherapy when treating your patients; we are interested in your day to day practices and your views. Nothing is 'right' or 'wrong'! The interview is expected to last for approximately half an hour and will take place at a location of your choice.

I will take notes during our conversation and will write them up after the interview. They will be returned to you to check that they are a true record of your views; you may add to or change the notes at this stage. The main themes in your report will then be identified and you will be asked to check that these are a fair reflection of your views. All information about you will be confidential and at no point will you or your work place be identified in any of the reports.

Please feel free to contact me at any time at the address below if you have any questions or would like further information:

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Consent form: phase 1

CLINICAL USE OF ELECTROPHYSICAL AGENTS

I have read and understood the information sheet provided about this study. I understand that notes will be taken of the information I provide and will be returned to me for confirmation that they are a true representation of my views and that I shall be able to alter them if necessary.

I also understand that the information provided will not be ascribed to me in any publications and that my anonymity will be respected on all occasions.

I therefore agree to take part in the above study.

Signed:

Full name in capital letters:

Date:

APPENDIX 2.

CLINICAL USE OF ELECTROPHYSICAL AGENTS: PHASE I

Standard introduction:

1. Thank you for agreeing to be interviewed!

2. As you know we are interested in the use people make of electrotherapy in their daily practice

3. I know you have read our information sheet but let me just remind you of what we are doing; we would like to know about your use of electrotherapy in daily practice. This is to help us direct future research in the most useful and profitable directions and to help us plan relevant undergraduate and post graduate educational programmes.

4. I would like to focus on a number of specific aspects of the use of electrotherapy but please also feel free to tell me anything you feel important about your use of electrotherapy and the 'hows' and 'whys' of your usage. We are trying to find out all we can about the matter!

5. Let me assure you again that neither you nor your department will be identified in any of our work.

6. Do you have any questions?

7. Right, let me begin by asking you what equipment you actually have access to on a day to day basis.

APPENDIX 3.

CLINICAL USE OF ELECTROPHYSICAL AGENTS: PHASE I
INTERVIEW NOTES

Subject 1.

1. Equipment available: US (pulsed and continuous), CSWD, PSWD, IF
2. Would like TENS and laser, but lack of finance
3. Some reservations about use of ET in general; many of the effects attributed to it could be due to placebo effects
4. Seen some excellent results with laser in previous department, especially with recent cuts
5. Mainly use US, PSWD and IF
6. Never use CSWD; heat seems to exacerbate many problems; others don't really need it; patients can use hot baths or water bottles at home and get the same effects
7. Always use fairly low doses with US and PSWD; between 0.5 and 1.5 W/cm^2 either continuous or pulsed (1:1); use level 1 or 2 with the PSWD
8. Choose between them on the basis of size of lesion, and whether the lesion is open or closed
9. Not much difference between US and PSWD; both can produce heat and can result in non-heating effects
10. US is better for reducing scarring; probably the micromassage effects
11. Use IF for swelling and pain; much better than US or PSWD
12. Don't really know much about laser
13. Not sure about the underlying effects of some of the agents; they seem to increase circulation and ultrasound has a micromassage effect
14. Manufacturers information is poor but main source of knowledge about PSWD, IF and laser
15. Progression of treatment: normally by time rather than intensity; same for all types of ET.
16. Give two or three treatments and then change to some thing else if it does not work
17. Always give ET in conjunction with other treatments; eg. exercise, ice, advice
18. Some reservations about efficacy of agents, especially PSWD and US
19. Placebo effects likely to account for much success; patients like the equipment and the time spent with them

Subject 2.

1. Equipment available: US (pulsed and continuous), PSWD, IF, laser, IR, UVR (theractin and kromayer), rebox
2. Use a lot of ET in practice, especially with recent soft tissue injuries
3. Mainly use US, PSWD and laser; can not afford laser; not want it as do not know enough about it
4. Got rid of the CSWD machine as it was old and were not using it; have not missed it
5. Heating is not really useful expect for relaxation and there are other ways of doing that
6. Low dose always; laser about 1 joule in two or three places; US pulsed 1:9 at 0.2 to 0.5 W cm2; CSWD lowest setting
7. No use treating for less than twelve treatments; can't tell before that if effective
8. Sometimes increase the dose a little depending on reaction of patient
9. Usually increase time rather than intensity
10. Always stop immediately if it seems to make people worse
11. US is great to stop scarring; can give it in water for open lesions if careful
12. PSWD is better for pain
13. PSWD is better for larger lesions
14. Can be given together; always give one first and then add the second
15. Undergraduate training: taught about CSWD, PSWD, IR, UVR; nothing about the others
16. Learned most from colleagues and experience
17. Postgraduate training; been to two courses; one very helpful about US; the other about IF was a waste of time
18. Course can be difficult to get to; time off; cost; travel
19. Mainly use ET with acute lesions
20. Chronic lesions usually need something more dramatic

21. Physiological effects are unclear; not sure what they are; some increase in circulation, reduce inflammation, reduce scarring (especially US)

S_bject 3.

1. Equipment available: US (pulsed and continuous), CSWD, PSWD, IF, laser, IR, UVR (theractin, Hanovia lamps and kromayer), faradism, TENS,
2. Use them all at different times; no problems acquiring equipment as need d
3. Heat is great for the elderly, use it a lot, especially for joints (eg OA); they feel more comfortable and relaxed
4. Heat given for up to twenty minutes; mild gentle
5. IF is brilliant for swelling
6. US and PSWD used for soft tissue lesions; especially bruises, tears, post treatment pain
7. Most doses kept really low, especially if the injury is acute
8. Some times use continuous US at about 1 W/cm^2 on large areas; can't see the point in pulsing if there is a large area to cover
9. Progression is always by time ... seems to work better
10. Two treatments given; if no better change to some thing else
11. Different patient seem to react differently to different treatments
12. Postgraduate courses: US, laser, TENS; all quite useful
13. Wish there was more information available about the different agents
14. Clinical trials needed but we don't have the time ... or the experience
15. Not sure about using electrotherapy in some patients; can't quite determine what effects are really taking place
16. With acute injuries it could be natural progression that is observed
17. Have the laser because it was introduced by the manufacturer; on loan, liked it so we kept
18. Would not buy another one (laser); it's not used very often now
19. Choose agents depending on the size of the area to be treated and dangers, contraindications; IF not suitable for skin that's in poor condition because of the suction cups; US can't be used for open wounds because of the gel or water
20. ET is important but as an adjunct
21. Wouldn't like to be without it
22. Often use US and PSWD together for soft tissue injuries; have tried laser and PSWD but not so good
23. Sometimes use ET alone eg bursitis, OA, tendon lesions

Subject 4.

1. Equipment available: US (pulsed and continuous), CSWD, PSWD, microwave, IF, IR, UVR (theractin and kromayer), faradism, TENS
2. Mainly use US, PSWD, IF and TENS; can only use the smaller equipment when out on community (US, TENS)
3. Can't afford laser; don't really want it as don't know if it works
4. Don't use the IR; been around for ages; very old equipment
5. Dosages are always low for US and PSWD; always pulsed for US (1:4 or 1:1)
6. Tend to use the same dosages all the time; altering them doesn't seem to make a difference
7. Tend to use slightly higher doses for chronic lesions than acute; found that best from experience
8. Tend to increase time rather than intensity
9. Treat for up to a week with ET, if it hasn't worked by then normally doesn't
10. Always use ET with other form of physiotherapy; often exercise, mobilizations, etc
11. Never use two forms of ET together; can't tell if one or other is working
12. Never seen any damage from use of ET but always use low doses so that may be the reason
13. Only recently acquired PSWD machine as it was expensive; boss not see need for one before that
14. Undergraduate training: was taught about SWD (continuous), US, IR, UVR, Faradism; masses of practice and not much theory so difficult to be clear about what is going on
15. It could all be psychological ... it s difficult to know ... definitely some psychological benefits even if physiological ones occur as well
16. S me reservations about using ET because not sure if really effective; difficult to tell as al ys

use it with other treatments

17. Could manage without ET; don't think patients would suffer
18. Thermal treatments are good for the elderly; they help them settle down before anything else; but not used often
19. US and laser can only be used locally; not useful for large areas such as joints and muscles

APPENDIX 4.

Information sheet: phase 2

CLINICAL USE OF ELECTROPHYSICAL AGENTS

Physiotherapists have been using electrotherapy for many years to treat a wide variety of conditions; agents have included long wave, shortwave and microwave diathermy, faradic currents, direct currents, infrared and ultraviolet radiation. More recently, ultrasound, TENS, new forms of stimulating currents and laser have joined the repetoir.

Research is needed to find out what the benefits are of each of these agents; there is, however, a limit to the time and resources available for this purpose. A number of recent surveys have looked at the types of equipment that are held by clinical departments around the country but this doesn't necessarily tell us what is being used (Ide and Partridge, 1986; 1989). One or two other studies have also looked at the way single items of equipment such as ultrasound have been used (ter Haar et al, 1987) but informal reports from clinicians suggest that practice may be changing with the introduction of new agents and clinical techniques.

We would therefore like to find out what clinicians have available to them, what they are currently using in clinical practice and how they are using the different forms of treatment. This information will also help us to focus our research on the most important areas. In addition it will provide information which will help us to adapt and rationalise the electrotherapy courses we run at the undergraduate level and develop useful postgraduate educational programmes to plug any gaps we may find.

We would like to start by asking you to tell us about the use you make of electrotherapy when treating your patients; we are interested in your day to day practices and your views. Nothing is 'right' or 'wrong'! The interview is expected to last for approximately one hour and will take place at a location of your choice.

Our conversation will be recorded and I will subsequently transcribe it in full. The main themes from our conversation will then be identified. We are primarily interested in group practices and opinions. All information about you will be confidential and at no point will you or your work place be identified in any of the reports.

Please feel free to contact me at any time at the address below if you have any questions or would like further information:

Sheila S Kitchen,
Physiotherapy Group,
Kings College London,
Normanby College Campus,
London SE5 9RS

Tel; 071 873 5215/ 5216

References:

Ide L and Partridge C J (1986) Survey of electrotherapy equipment in physiotherapy departments in 1986. Available from the Chartered Society of Physiotherapy, London.

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Consent form: phase 2

CLINICAL USE OF ELECTROPHYSICAL AGENTS

I have read and understood the information sheet provided about this study. I understand that the interview will last for approximately one hour and that it will be audiorecorded and subsequently fully transcribed. I also understand that the information provided will not be ascribed to me personally in any publications and that my anonymity will be respected on all occasions.

I therefore agree to take part in the above study.

Signed:

Full name in capital letters:

Date:

APPENDIX 5

CLINICAL USE OF ELECTROPHYSICAL AGENTS: PHASE I

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APPENDIX 6

CONDITIO'S TREATED / SYMPTOMS TREATED

Lot of chronic conditions

Arthritis largely

Neuro patients with associated soft tissue lesions

Phantom pains

SWD - postural deformities, tightness in the shoulder and back, muscle spasm

For spasm which is part of the arthritic process I use SWD

Pressure sores very low doses PSWD if not infected

US just used occasionally for more acute things like supraspinatus tendinitis

US - I like this for acute injuries - tendons ligament and muscles

I've never used it for the nervous system directly (US)

I use SWD on capsulitis before manual stretch -always

SWD on knees too

Laser - used on dural sleeve

I've tried to use ET for soft tissue lesions and pain

I use it (laser) on chronic things like tendons

Laser - for tendons ligaments wound healing, fantastic result with herpes. Bursa no success. Nothing else

PSWD I'm not convinced of its use for pain or swelling

PSWD/SWD on backs - I'm not convinced

US tendons, crepitus, haematomas, dupuytren's contracture,

Don't use heat on any joints

I use ET for pain - to break down adhesions - to reduce spasm

Heating (US) mainly for arthritic and chronic conditions

the scar tissue (US)

Soft tissues are better treated with US nerve tissue with IF

US for ligament and tendon

Mostly acute and chronic soft tissue lesions - muscle, tendons, ligaments

I use it (US) for pain and swelling - it's like IF but more local

I use it (US) for haematomas -it's more penetrating - I read that somewhere

US strains muscle, ligament and tendons

SWD used rarely for OA type conditions

Mainly used for swelling (SWD)

I use PSWD for acute conditions

PSWD is very good for bruising and haematoma

I usually use it (CUS) for chronic types - ligaments tendons, ankles
shoulders OA tears

I usually use PUS for acute things -especially tendons , soft tissues ; never nerves

Leg and shoulder injuries mainly - ankles ligaments tendons, muscle tears

I use laser for small areas of pain or open wounds

I mainly use it (laser) for soft tissue healing

Laser - Best for superficial inflammatory conditions - tendons, superficial muscle tears ligaments

Laser is best for clean wounds and healthy tissue - surgical wound and cuts

Trigger spots - very tender spots I tend to use laser

Sprains, swelling haematomas (PSWD)

I've found it very effective to relieve treatment soreness (PSWD)

I use it (PSWD) for very acute things backs necks, RA, after mobilizations

I might use the US for sprains and strains

I used the laser for some diabetic ulcers

I used it (Laser) on a kick too

I use it (laser) to settle inflammation

It (laser) did nothing for tennis elbow

I give US to ankles when they are 3 - 4 days old

I mobilize soft issues with US

SWD is good for sickle cell joints

Occasionally use it (SWD) for pelvic inflammatory conditions

US works on (soft) tissues

I occasionally use SWD for sticky knees

US has its uses - hands, dupuytren's contracture, haematoma

I might use CUS on bursitis

I use US for pain

It (US) has some effect on scar tissue

DOSAGES

Doses - by rule of thumb

Never give SWD for more than 20 minutes - that's purely personal

First treatment for 10 minutes, then 15 and 20 if OK

SWD never less than 10 minutes

SWD for a very gentle effect

Thermal sensation difficult with the elderly - from experience I know the point on my dial that gives most people a gentle warmth

Never increase SWD beyond mild - that was drummed into me

Very mild warmth - not even feel like a nice hot water bottle

Very very mild with every thing

I err on the side of caution

I don't increase the dose for the depth

Usually use 3 MHz

Don't know what parameters my machine has - no choice

Intensities and doses always the same

US I would use up to 2 W/cm^2 depending on lesion

I always use a low does of US about 0.5 W/cm^2 - occasionally 0.8 for chronic lesions if I want to get a good sonic mobilization of the scar tissue

I use a very low dose - pulse it 1:1 or 1:4 as that is all the machine has.

1:4 for very very acute conditions because I'm quite happy with it - not a very scientific reason I know!

I don't need any other lower pulsing - I have a gut feeling that 1:4 is OK

1:1 I use most of the time for medium cases - sort of subacute

It seems just common sense - a half way dose for intermediate lesions

I give 2-3 min for acute lesions; 5 for deeper lesions; 6-7 for larger lesions

Just decide on the basis of common sense visual guess work, I guess

You must use low doses (US)

Frequency is more important than intensity with US

I give up to 6 minutes treatment (US) - I don't have time to give any more - anyway its enough

I only use very low doses they can only just feel the warmth (SWD)

It doesn't need to be higher - about 100 on the dial (SWD)

Probably only give it for about 10 or perhaps 15 minutes (SWD)

PSWD I use high doses - 100 pulses or more

I'm not sure why I don't use continuous (US) - it just seems sensible not to

You just decide how many joules you want to give - 1 J no good - I give 2-3 J per square cm (laser)

For acute lesions I use 1:9 pulsing, .2 or .3 W/cm^2

Chronic lesions I use continuous US and possibly up to .5 W/cm^2

I use laser continuously rather than pulsed

I use it (US) pulsed

It (US) tends to be very low doses that I use

I don't know about dosages (PSWD) - its difficult to tell from the machine

I just play around and ask the patient next time how it was (PSWD)

I never go up towards the maximum (PSWD Dosages)

I always use US pulsed and about .25 W/cm^2

For chronic lesions I would increase it to .5 $W\ cm^2$

A really low dose (laser)

I used the manufactures instructions but they were really poor so I just used the lowest dose (one out of five levels)

It's 906-963 nm and it has to be pulsed

The timing was pure guess work (Laser)

The manufacturers suggested 20-25 minutes - I wasn't so sure so I did about 10 minutes

I use below 8 mean Watt for acute things (PSWD) - always for first treatments

I never use US for more than 3 minutes

I'm not sure about the dosage with laser - I use the omega one on a frequency 2 or 3 - it's not in joules I don't know what it means

I'm not sure how to work to dosage (laser)

I can't see any difference between the frequencies but I don't really know

PROGRESSION / DURATION / FREQUENCY

Changes in heating depend on what patient says and I see

Never increase SWD beyond mild - that was drummed into me

If they go red and blotch -it's too much

I tend to under treat first and then bump it up to what they (the manufactures) suggest

I try it (US) for three sessions first to see if it will work before changing

Never increase the dose after first time - usually after second - again that's down to experience

I don't increase the time or intensity with US

SWD I progress time only

Don't go on for ever 8 - 10 treatments

3-4 treatment usually takes up about ten days to a fortnight - would need that much time to see an effect

I stop after 3-4 treatments if they are not better or stay the same

I go on giving treatment for about twelve times - then I would think twice before going on

I give up to 6 minutes treatment - I don't have time to give any more - anyway it's enough

I stop US treatment after 10

I usually only increase the time (SWD)

I only use it for 3 or 4 treatments - never 10-12 (PSWD)

Tend to treat people 2 or 3 times a week (PSWD) - I think the effect probably lasts that long but I don't know

I don't usually give patients more than 2 or 3 treatments (PSWD)

Progress time before intensity (US)

I only give a treatment (any ET) 2 or 3 t'mes usually - it de ends on how they are

If they are not getting better after 2 or 3 treatment is re-assess

But I just go by what people say the effect is the next time they come in for treatment (PSWD)

Chronic patients may come in for a month (PSWD)

I just play around and ask the patient next time how it was - if it helps I carry on (PSWD)

It responded well so I carried on (laser)

If there is some improvement I keep it that way (PSWD)

FACTORS AFFECTING SELECTION OF AGENT AND DOSAGE

When choosing between pulsed and continuous SWD I think about the contraindications - like circulation; I give pulsed if there is any problem

Tend to use higher doses for chronic conditions

Laser for chronic rather than acute

US similar but more acute lesions

How much I give depends on the depth of the lesion - not how acute or chronic it is

US usually for acute conditions I use it a lot

It seems just common sense - a half way dose for intermediate lesions

I give 2-3 min for acute lesions; 5 for deeper lesions; 6-7 for larger lesions

Just decide on the basis of common sense - visual guess work, I guess

I vary the treatment according to the depth of the lesion - US goes deeper

I vary the treatment according to the area of the lesion

I use it (US) when I don't know what to do

I favour US because of its ease of application

Treatment is based on symptoms - such as pain swelling

I use US for local stuff

Sometimes I get bored with US so I change to IF or frictions - you've got to balance the environment for yourself

For acute lesions I use lowest pulsing 2:8 (US)

Continuous US for chronic lesions

US saves time

I treat on a symptom basis

Very much symptom based treatment - I treat for what I find rather than what it is

Patients like it (SWD) - it's comfortable

Treatment is symptom led I see how they are, how they feel

I often choose US instead of PSWD because of the size of the part

I choose US for collagen type things

I don't really choose US f r pain

I choose PSWD for muscle things

Older people can't take ice so I use ET

If its a large or deep area I don't use it (laser) - if its large its too time consuming - if its deep it won't penetrate that far

If the skin is black I increase the dose a bit (laser)

I don't use it (US) when there is bleeding or it is likely to start - not for the first 24 hours

For acute lesions I use 1:9 pulsing - .2 or .3 W/cm^2

Chronic lesions - I use contin ous US and possibly up to .5 W/cm^2

For deep injuries I tend to use US

General use over larger areas I go for US

Laser won't get down to the deep things

PSWD used for very acute lesions when its too soon to use US

I do use PSWD quite a bit when its very acute and hot not infected

I use it (PSWD) particularity when I'm a bit dubious about hands on

Medium doses for long term chronic things

PSWD is easy to manoeuvre - easy to set up when something is painful

US is such a local treatment - it's only useful for very local lesions for tender spots

For chronic lesions I would increase it to .5 $W\ cm^2$

PSWD - if it's acute - 2 or 3 treatment should have an effect - for chronic things - you may have to persist for longer

People often put people on ET if they are busy

(I give doses) on the basis of gut feeling

Oc asionally I pile in the whole lot - especially w en it's one of these difficult situations when you just didn't know what to do

I treat on the basis of symptoms - each time they come

I treat all acute injuries with PSWD

It's a gut reaction doing it this way

Everything is based primarily on experience

Acute things are already engorged so you don't want to increase it by heating

I didn't have SWD for a long time but felt that I needed it for chronic things

Higher doses for chronic things

If there is something I know I can't do any harm with I may try continuous US - its based on gut reaction

US has a very local effect

I use it a lot for fingers - you can get at them with laser

I use the laser for convenience of size

I use laser on immediate injuries - and PSWD

THERAPEUTIC EFFECTS

Pulsing gives some idea of some heating and cooling

The idea is to increase the circulation, remove waste products

PSWD I use it as a thermal modality

It related to circulation, pain and spasm

(PSWD) increases the circulation

I don't think the thermal effect is significant (PSWD)

US I think it helps to loosen adhesions and increase circulation

Pain is affected by US

Any dose (US) affects the circulation

US - it also has a mechanical effect - it helps fluid absorption if there is any swelling

(US) it helps with pain relief

I really can't say if it (US) directly affects pain

It (US) helps with the whole healing process and therefore must help the pain

I use pulsed US when I don't want any heating effect

I think of US as mobilizing scars at a molecular level

If you over do US you can have a pro-inflammatory effect

US definitely helps - it works for pain and affects absorption

SWD heating helped their pain a lot

I think it (SWD) increased the circulation

PSWD must be affecting the circulation, absorption of fluid that sort of thing

I'm trying to remember my theory - I think it (PSWD) affects the cell

It (US) increases the circulation and softens the collagen

Maybe its helpful because of the massage effect

There are lots of nonthermal effects of US

Wounds heal more quickly - about half to 2 3 of the time (laser)

I haven't noticed so much scarring with laser

Inflammation seems to be quicker - not miss out any stages but faster (laser)

I think it (US) affect metabolism, circulation, calcium exchange, micromassage effect, tissue elasticity

They have an anti-inflammatory effect - not relieve pain except through inflammation

It reduces swelling in more chronic conditions - at least in theory

I use it to reduce swelling to balance things over the cell membrane - oh I've forgotten!

PSWD also affects circulation - but not through heating

It (heat) certainly has a pain relieving effect -its relaxing- especially with the elderly

It (US) definitely helps to mobilise the soft tissues and relieve pain

My aims are to reduce inflammation and pain

US has a micromassage and pain relieving effect

There is probably some thermal effect with US

ADVERSE REACTIONS

With US I sometimes find that you can get a sudden sharp pain - though I was moving it around fast enough

It must have been a sudd n heati g effect or something - possible bone - I d n't know - it didn't happen again (US)

I've had no adverse effects with PSWD

SWD can make people feel giddy; I always let them rest

Sometimes you get exacerbation of symptoms - mainly with thermal treatments - maybe the condition was more acute than you thought

US can give rise to sudden pain over bony points - not my technique - always in contact

Laser once increased inflammation

PSWD no problems; SWD some times seen a burn

Few side effects

US occasional gave sharp pains; not for all patients - may be over bony points

I've found no adverse effects with US - just the occasional tingling; some people get it worse than others - I get it myself

I had adverse effects with US almost every time before I started using it at doses of less than 0.25 W/cm^2 - I was less experienced and probably too enthusiastic

I can't be sure it was the US giving problems as I over did everything; I don't know if the problem was the US or the frictions

Occasionally get sharp pains with US - always stop if I do; have the machine checked; usually find a fault in the machine like loose wires or connections

Sometimes you get a surge over a bony point - US can give a sharp pain

I've not had any adverse effects with SWD or PSWD

I had one bad effect with US - it was over an elbow; I think it was probably reflection - they got a sharp stabbing pain. It went away immediately and didn't happen again

ET has never made things worse

I once overdid the US and the patient came back with a REAL ache

US can produce sharp pains - like a pin prick - mainly over bone

It could be standing waves (sharp pain)

I've had no problems with laser

Once it was a bit more painful after treatment with laser but people say that's a good thing with laser - It's a space laser - the blurb says that if there is an increase in pain for a short while it's a good sign - it means you have hit the tender spot

SWD can produce aching - if it doesn't go off I don't do it again

They say they get bone ache (PSWD)

Occasionally you get discomfort with US

I once had someone who had a sharp pain with US but I think I kept the head still by mistake

I did get some discolouration of the skin in a black man with laser - but it improved; I read about it immediately afterwards

ET AS AN ADJUNCT

Very very rarely use ET on its own

Can't remember when I last gave ET alone

I don't often combine things - but only for person reasons

I have this idea that if you use too many things (agents) you won't know what is working

I do tend to use one (ET agent) and then change to another

I don't usually add things (ET agents) on

It may be silly because it could be that a combination is what works - but until I've got it sorted out in my mind that one or other is effective I won't do it

Draw back from using too many things (ET agents) at once

Combination of the two very good - start with frictions then add US

Not begin both together as I want to know which is working

Wouldn't feel happy to use any two modalities together

Not really happy with what's happening - even less so if using two

Never use US on its own

Don't use things (ET) together - couldn't tell what was working

Sometimes switch from one to another (ET agent) if not sure if something is joint or soft tissue

I'm sure I do occasionally give ET on it's own; I do it when I'm short of time sometimes or can't think what to do

Mostly give ET with other things

Patients want value for money - there's an element of showmanship in the whole thing - I give them the lot

Advice with regard to home is usually most important with ET

I follow frictions with US - it's a back up

I alw ys use other things as well - ice, strapping, mobs

US he ps but not on it s own - it's additive

Somet mes I use US and IF together

I don't use it on it's own (SWD)

Always use SWD with other things

I don't use things (ET) together but I don't see why you shouldn't

I often use laser and US together - not for open wounds but for closed

I normally use other measures as well

I don't tend to use one modality on its own

The combination of treatments may change as it improves

Chronic lesions I make them acute with frictions and then use laser plus US

Often laser and US together

I don't know if using both (US and laser) will enhance the effects

I definitely add other treatments

I never use PSWD alone - except occasionally with very old patients such as RA patients who can't tolerate being pulled about

PSWD laser and US all have fundamentally the same effects

I've tried putting PSWD and US together

I don't think it made any difference (2 together) - but it's guess work

Sometimes I give it (US) after mobilizations and sometimes before

I've found that if you give mobs and then test and then give US and test again they are better after the US

I never use it (US) entirely on its own

(I use it on its own) on occasions when I haven't got the time to see someone

I will add things but only one at a time - I then reassess

I never use ET without hands on treatment - unless for lack of time

I can't decide whether its better to use ET before or after treatment - I tend to do it first - I think quite a lot about it - I can't decide

I rarely use US on its own - I usually add IF

I normally combine US with IF or PSWD

SEQUENCING OF AGENTS

I'm sure there is a connection between using US first then laser - I've had to do it so many times - and it works

You seem to get to a point where your not sure if your making any difference switch at that point laser does it straight away

Never tried reversing that (laser to US)

Always try US first as I know more about it

No I don't switch form US to PSWD - I might change to something else if its not working

I tend to use laser first then US

I try something 2 or 3 times and then try something else

Yes I do change from one modality to another

Switch from PSWD to US and other way round

People tend to plateau and need a change

Patients wonder why we chop and change between machines - people respond differently

I sometimes change for the last couple of treatments - for example from IF to PSWD

It (changing) can make all the difference

I tend to use one (ET agent) at a time and then switch to another

Some times I switch from one to another (ET agent) if I'm not sure if something is a joint or soft tissue (lesion)

SIMILARITIES AND DIFFERENCES

There are differences - I wouldn't interchange SWD and wax

Things are not interchangeable

PSWD and PMW are interchangeable so no need for both

US can be alternative to SWD but more local - heats the same way

PSWD and US are more or less interchangeable - but not completely

Laser and US are probably interchangeable

Laser and US have very similar effects

Machines of different kinds - different agents - are interchangeable

PSWD laser and US all have fundamentally the same effects

SWD and PSWD are not similar

Physiologically - they (PSWD, SWD) can't be the same can they? No - they are similar effects but to different degrees

I don't think US and laser are interchangeable - but I'm not really sure about the laser

<u>ATTITUDES TO ET : BELIEFS ABOUT EFFICACY</u>

I've had some good results

They feel better - looser- less pain

You get long term effects - nothing for the first 3-4 weeks

US - I don't use it much; I haven't seen the benefits - but I'm sure it does work

Laser - I'm concerned about it

ET is not always my first choice due to lack of evidence

I'm not hooked on thermal treatments

I've never been convinced by the effects of heating

It (SWD) will relieve the pain but I've not seen long term results from it

PSWD - I didn't see much effect - wasn't convinced

I stopped using PSWD because it was working - it masked the effects of manual treatment

Haven't used continuous (SWD) for some time - a feeling really

Don't get dramatic results with chronic conditions (with PSWD)

I'm very sceptical about laser

You won't see an immediate effect (US) 3-4 treatment before any change I tell my patients that

Occasionally see immediate effect - my private patients sometimes ring after one treatment to say they are better (US)

I don't always bother to take ET out with me (to the community) - I think they may loose out a bit but I don't know how much

I can't afford a laser and I'm not really bothered

I never use PSWD I don't know much about it - I don't know so I don't use

I've not really thought about using PSWD

It certainly helps the pain and seems to help any swelling that's there (SWD)

The bruising seems to come out after PSWD

I know it works at a cellular level - in vivo I'm not so sure (PSWD)

Maybe things would get better anyway

I THINK it works - you can't be sure when you do so many other things (PSWD)

I think the patient get better more quickly (if you use PSWD)

I think it works (US)

Tho gh I have had one or two dramatic results (US)

No I don't want a laser - I'm happy with what I've got

It's so difficult to know if it works when you are using so may treatments

I don't know what would happen if you left it (ET) out - I think it probably get better but it would be a bit slower

(Laser) Heals very nicely and very quickly with laser

I've tried it (Laser) over acupuncture points but I'm not very sure - I haven't much experience

I think it (laser) works

I'm happier with US

I missed the laser when I didn't have it

Since I've been pregnant I've cut out as much ET as possible

I'm not sure what is really working

The effect of PSWD varies - sometimes it is very effective and sometimes it doesn't work

It all seems to be a bit hit and miss

It's all very subjective

I'm not sure if it (PSWD) works

If I had no ET I could still treat the patients with very few exceptions

I don't use US frequently now

I have my doubts about it (US)

I think most of the ET effects are arbitrary - sometimes changes just happen

It (Laser) worked wonders

I don't think I could have achieved that good a result with PSWD or ice

It's (Laser) my last line of choice

For safety reasons I'm using less ET while I'm pregnant

I don't think the patients have missed out - except for those with very obvious inflammation and swelling (on not having ET while I'm pregnant)

Y u shouldn't underestimate the effects of heat

PSWD doesn't do any thing more than the others - I don't need one

There is the danger of too much ET being used - but then there is the danger of poo-pooing it

(ET) can be very useful

I wouldn't throw it (ET) out but I'm not totally convinced

I've had some good effects with the laser

PLACEBO / PSYCHOLOGICAL EFFECTS

A lot of the effect is probably due to the fact that the patient can feel the heating

Very useful - the patients feel positive about it

They are feeling something

With our patients it is almost as important that they feel something as it is as to whether it does any thing

Some patients respond well to heat because they like it - I might give it to them

There are lots of placebo effects of laser - here we have an isolated room - I'm not sure if the results are due to the laser or the room

Placebo is part and parcel of laser working

The omega laser is amazing - all the lights!

It's for psychological reasons - not often - I feel a bit of a hypocrite

PSWD looks dramatic

It could be psychological

It could be psychological - time is given to them. They have time to settle down after an uncomfortable treatment

I don't really choose US for pain - though I have had one or two dramatic results Maybe it's psychological

There is something about just sitting down with a patient for five minutes and giving them all your time - just treating the patient yourself - you don't go off and leave them on their own. It gives them a chance to settle down - maybe it's all psychological

I don't know if it is all placebo

They still say they feel better if you forget to turn on the laser or forget to plug it in

I'm sure there is a big placebo effect

The placebo effects are similar in all ET

People like laser - they can't wait to tell their friends they have had it

Occasionally I use SWD mainly for the psychological effect

Maybe its psychological

There are lots of flashing lights - it keeps every one happy

If I don't give it to those with psychological problems - no matter what else I give them it won't be effective, I suspect

Heat is what they notice - it may be psychological but it's effective

Sometimes I do wonder (US) - you get a patient who says they are so much better and you realise that you haven't turned on the machine

Maybe it's just that somebody is taking care

They think you are really trying to help so it works

You get some relaxation with ET - maybe it's psychological

Patients said they felt better 'Must have been the laser' they said - maybe its psychological

Sometimes I have patients that I can't do much with now but may be able to later on - I have to maintain their interest and keep them coming so I give them ET Its not doing them a hell of a lot of good. People with psychological problems need to be plugged into the mains

It does the patients good to come in and chat - and we are seen to do something for them (PSWD)

Sometimes use things if people need something DONE to them - they will cooperate better with exercises afterwards

Lots of people find simply having it done very soothing (US)

I think I use ET just to convince patients

Sometimes I give people ET to keep them happy - to keep them coming - or to fill in the time before I can do something else with the problem

I do it to maintain their interest

I mix ET with psychology - you have to interest them

SOURCES OF INFORMATION

Quite important part of training course (ET)

PSWD - just pick it up as you go along

Laser - no; I have no real knowledge of this; I don't know enough about this; read a few articles.

In our training we got quite a lot about ET

SWD - not pulsed - lots on US (training)

Omega came and explained - we thought we understood - then they came ba k six months later they'd changed their minds - that finished me off. They couldn't support why they had changed their views. No explanation; no research. You misheard the first time (laser)

When I asked the manufacturers about the lasers they had no idea what you were talking about - it was very difficult.

SWD techniques updated by reading

Course on PSWD

My husband worked in laser before he died - I don't see how they could work

I was taught both continuous and pulsed US during training

I went to Mary Dyson's lecture on laser - it sounded interesting

I found out the things I know from usage not papers

Caroline suggested it

I saw them (Lasers) in Australia - they were OK but I didn't see much benefit

Saw laser when training; reps, trials

I went to Mary Dyson's lecture

I'm more familiar with US - I was taught it

I was taught US

Laser - I learned about through study days - a couple of company days

Lots of education seems to be through the reps - it's unfortunate as they only tell you the good things

I have one book about laser - it's Dutch and very anecdotal

I use the manufacturers literature

And in-service training

Really I just experiment and try to use the instruction book

I used the manufactures instructions but they were really poor so I just used the lowest dose (one out of five levels)

The manufacturers suggested 20-25 minutes - I wasn't so sure so I did about 10 minutes

It's a space laser - the blurb says that if there is an increase in pain for a short while its a good sign - it means you have hit the tender spot

Most training is from the manufacturer's stuff

I've read a few articles - mainly about skin stuff

You play according to experience - though there's a lot of experience behind it

Is it a good thing to let them play around (with ET) - they want to get it together

You forget that you learned with experience

It's almost impossible to explain

I've had a couple of courses on pulsed ET

Mostly I read it from the books

I get my information from the info from the manufacturers and from chatting to people

APPENDIX 7

No: 10 . 11

25

KINGS COLLEGE LONDON: PHYSIOTHERAPY GROUP

ELECTROTHERAPY TREATMENTS AND SOFT TISSUE LESIONS.

Thank you for agreeing to help us gather information about the selection and use of electrotherapy treatments (ET) for the management of soft tissue lesions. In this questionnaire we shall be concentrating on ultrasound (US), shortwave diathermy (SWD) and laser (L).

There are no 'right' answers to any of the following questions! We would like to find out about <u>your</u> practices and views in each area.

I. PRELIMINARY QUESTIONS

1. What is your present clinical grade? Please place a tick (✓) in the box provided.

Staff	☐	Senior I	☐
Senior II	☐	Superintendent or above	☐
Other	☐	Please specify	

2. Which of the following types of electrotherapy equipment do you have available in your department for the treatment of patients?

continuous ultrasound	Yes	☐	No	☐
pulsed ultrasound	Yes	☐	No	☐
continuous shortwave diathermy	Yes	☐	No	☐
pulsed shortwave diathermy	Yes	☐	No	☐
laser	Yes	☐	No	☐

II. FREQUENCY OF USAGE.

3. The frequency with which the different forms of electrotherapy treatment are used by therapists for the management of soft tissue lesions varies greatly.

Please indicate which of the following statements most closely reflects your usage of the following types of treatment over the last six months: continuous ultrasound, pulsed ultrasound, continuous shortwave diathermy, pulsed shortwave diathermy and laser. Please place a tick (✓) in the box provided.

	CUS	PUS	CSWD	PSWD	LASER
most days of the week	☐	☐	☐	☐	☐
once or twice a week	☐	☐	☐	☐	☐
2 or 3 times a month	☐	☐	☐	☐	☐
less than once a month	☐	☐	☐	☐	☐
never	☐	☐	☐	☐	☐
not applicable	☐	☐	☐	☐	☐

III. SYMPTOMS TREATED

4. Some therapists manage soft tissue lesions according to symptom rather than diagnosis. The following are a list of symptoms commonly treated by the use of electrotherapy.

Please indicate whether you have treated any of the following, irrespective of diagnosis, with either continuous ultrasound, pulsed ultrasound, continuous shortwave diathermy, pulsed shortwave diathermy or laser over the past six months by placing a tick (✓) in the box provided.

Symptoms	CUS	PUS	CSWD	PSWD	LASER
pain	☐	☐	☐	☐	☐
spasm	☐	☐	☐	☐	☐
oedema	☐	☐	☐	☐	☐
scarring	☐	☐	☐	☐	☐
haematoma/bruising	☐	☐	☐	☐	☐

Key: CUS - continuous ultrasound CSWD - continuous shortwave diathermy
PUS - pulsed ultrasound PSWD - pulsed shortwave diathermy

IV. LESIONS TREATED

5. The following are a list of soft tissue lesions commonly treated by the use of electrotherapy.

Please indicate whether you have treated any of the following with either continuous ultrasound, pulsed ultrasound, continuous shortwave diathermy, pulsed shortwave diathermy or laser over the past <u>six months</u> by placing a tick (✓) in the box provided.

	CUS	PUS	CSWD	PSWD	LASER
<u>Closed lesions</u>					
muscle lesions	☐	☐	☐	☐	☐
ligament tears	☐	☐	☐	☐	☐
tendon lesions	☐	☐	☐	☐	☐
bursitis	☐	☐	☐	☐	☐
fascial tears	☐	☐	☐	☐	☐

	CUS	PUS	CSWD	PSWD	LASER
<u>Open lesions</u>					
ulcers	☐	☐	☐	☐	☐
pressure sores	☐	☐	☐	☐	☐
surgical wounds	☐	☐	☐	☐	☐
traumatic wounds	☐	☐	☐	☐	☐

Key: CUS continuous ultrasound

PUS pulsed ultrasound

CSWD continuous shortwave diathermy

PSWD pulsed shortwave diathermy

V. USE OF ELECTROTHERAPY AS AN ADJUNCT

6. Many therapists use electrotherapy for soft tissue lesions in combination with other forms of treatment. The following statements have been made by therapists about such combinations.

Please indicate the extent to which you agree or disagree with each statement by placing a tick (✓) in the appropriate box.

	Strongly agree	Agree	Disagree	Strongly disagree
US, SWD or laser should be augmented by other forms of treatment such as advice, exercise or other physical procedures	☐	☐	☐	☐
US, SWD or laser alone are effective in the management of some soft tissue lesions	☐	☐	☐	☐

If you have ticked 'agree' or 'strongly agree' to this last statement, please list up to five types of soft tissue lesion for which you have found ET alone to be effective.

a ....

b ....

c ....

d ....

e ....

7. Many therapists <u>use a combination</u> of electrotherapy techniques in the management of soft tissue lesions. The following statements have been made by therapists about such combinations.

Please indicate the extent to which you agree or disagree with each statement by placing a tick (✓) in the appropriate box.

Sometimes it is useful to use some combination of US, SWD or laser
<u>during a course of treatment</u> Yes ☐ No ☐

Sometimes it is useful to use some combination of US, SWD or laser
<u>in one treatment session</u> Yes ☐ No ☐

If you have ticked 'yes' to this <u>last</u> statement, please could you list those combinations you have found useful.

a. ....

b. ....

c. ....

VI. SIMILARITIES AND DIFFERENCES.

8. S me therapists believe that the effects of the different types of treatment are similar and the agents are therefore interchangeable; others disagree. The following statements have been made by therapists about such similarities and differences.

Please indicate the extent to which you agree or disagree with each of the following statements by placing a tick (✓) in the appropriate box.

	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
I think the clinical effects of the following are quite different					
US and SWD	☐	☐	☐	☐	☐
US and laser	☐	☐	☐	☐	☐
SWD and laser	☐	☐	☐	☐	☐
The effects of the following agents are so similar that they are interchangable					
US and SWD	☐	☐	☐	☐	☐
US and laser	☐	☐	☐	☐	☐
SWD and laser	☐	☐	☐	☐	☐

If you have ticked 'agree' or 'strongly agree' in answer to any part of the <u>last</u> question, please list <u>up to 5 fa tors</u> that would influence your choice of agent:

a ....

b ....

c ....

d ....

e ....

VII. THE PLACEBO EFFECTS OF ELECTROTHERAPY

9. The following are statements that have been made by therapists about the possible placebo effects arising from the use of electrotherapy treatments.

Please indicate the extent to which you agree or disagree with each statement by placing a tick (✓) in the appropriate box.

	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
ET treatments are likely to give rise to a placebo effect	☐	☐	☐	☐	☐

If you have ticked 'agree' or 'strongly agree' in answer to the last question, please continue with the next two questions; if not, please move straight on to question 12.

10.	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
I think placebo effects arise from					
the use of electrotherapy	☐	☐	☐	☐	☐
most other therapy techniques	☐	☐	☐	☐	☐
interaction with the therapist	☐	☐	☐	☐	☐

11. Please rank the following types of electrophysical agent from 1 to 3 according to the level of placebo effect you believe they may have on the pateint. For example, if you believe that agent "X' would give rise to the greatest effect write a number 1 beside it. If you believe the placebo effects of two or more of the agents may be similar, place the same number next to those items.

Shortwave diathermy ☐

Ultras und ☐

Laser ☐

VIII. SOURCES OF INFORMATION.

Therapi ts gather information about electrotherapy treatments from many sources. P ease pla e a tick (✓) in the boxes which m st cl sely describe your experience and practice.

12. I received formal tuition in my undergraduate training about

continuous shortwave diathermy	Yes ☐	No ☐
pulsed shortwave diathermy	Yes ☐	No ☐
continuous ultrasound	Yes ☐	No ☐
pulsed ultrasound	Yes ☐	No ☐
laser	Yes ☐	No ☐

13. I have attended p stgraduate cour es (½ day or longer) including

continuous shortwave diathermy	Yes ☐	No ☐
pulsed shortwave diathermy	Yes ☐	No ☐
continuous ultrasound	Yes ☐	No ☐
pulsed ultra ound	Yes ☐	No ☐
laser	Yes ☐	No ☐

14. The following are statements that have been made by therapists about ways in which they have learned about the use of electrotherapy.

Please rank the following statements from 1 to 4, placing a number 1 against the statement which reflects the way in which you have learned most about the use of electrotherapy and a number 4 against the statement which reflects the way in which you have learned least about its use.

I have learned most about the use of ET through:

- discussion with colleagues ☐
- personal experience ☐
- reading the literature ☐
- attending courses ☐

Thank you very much for your help and for taking the time to answer these questions.

Mrs S S Kitchen MSc MCSP Dip TP

Kings College London
Division of Biomedical Science
Physi therapy Group
Normanby College
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Tel: 071 326 3171

Date

Dear Mx Somebody,

USAGE OF ELECTROTHERAPY

I am writing to ask whether you would be willing to allow a number of physiotherapists within your area to take part in a study to look at ways in which therapists approach the usage of electrotherapy in every day clinical practice.

Following the studies by Dr. Partridge and Dr.Dyson and their respective colleagues, which looked at equipment held by department and usage of ultrasound, we would like to find out a little more about how practising clinicians make use of a number of different pieces of equipment. Those we would like to look at presently are ultrasound, shortwave diathermy and laser. We hope that this work will help us to concentrate further research efforts into the fields of greatest interest to practitioners and also help us in the development of undergraduate curricula.

We are now asking people about their approaches to the use of electrotherapy through a questionnaire, and would like to take a sample from across the country. The questionnaire takes just over ten minutes to complete and does not require any special technical knowledge; we are interested in the views and approaches of the therapists in question. The results of this questionnaire will be totally confidential and no individual or group of therapists will be specifically identified. We are interested in the sample as a whole rather than individuals.

We would like to send the questionnaire to the staff working in one of the outpatient departments you are responsible for and would be very grateful if you would feel happy to identify such a group. We would then contact them directly with full details. It is appreciated that not all departments will have access to all three of these modalities but would appreciate it if they had access to two of the above!

We would be most grateful if you felt able to help us in this way. Please feel free to contact me by 'phone if you have any further queries at all.

With warmest thanks for your help,

Yours sincerely,

Sheila S Kitchen MSc MCSP Dip TP

USAGE OF ELECTROTHERAPY

Electrotherapy has been used in clinical practice since the beginning of this century and its use has clearly changed and developed over this time. Our knowledge of how therapists make use of the different agents and their approaches to its usage are, however, still very limited.

Following the studies by Dr. Partridge and Dr. Dyson and their respective colleagues, which looked at equipment held by departments and usage of ultrasound, we would like to find out a little more about how practising clinicians make use of a number of different pieces of equipment. We are particularly keen to compare the usage of a number of agents and those we would like to look at presently are ultrasound, shortwave diathermy and laser. We hope that this work will help us to concentrate further research efforts into the fields of greatest interest to practitioners and also help us in the development of undergraduate curricula.

We are now asking people about their approaches to the use of electrotherapy through this questionnaire, and are taking a sample from across the country. There are no 'correct' answers to these questions, which are primarily based on statements made by practising therapists of different ages and experience. We are interested in your views and approaches to the use of electrotherapy.
The results of this questionnaire will be totally confidential and no individual or group of therapists will be specifically identified. We are interested in the sample as a whole rather than individuals.

Please feel free to contact me by 'phone if you have any further queries at all.

With warmest thanks for your help with this project; we shall be letting you know how we get on!

Sheila S Kitchen MSc MCSP Dip TP
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APPENDIX 10

ELECTROTHERAPY TREATMENTS OF SOFT TISSUE LESIONS

Coding of q e tionnaire.

In every case:	not applicable	-	98
	no answer	-	99

Key: CUS - continuous ultrasound; PUS - pulsed ultrasound; CSWD - continuous shortwave diathermy; PSDW - pulsed shortwave diathermy; L - laser.

1.	Staff		-	1
	Senior II		-	2
	Senior I		-	3
	Superintendent or above		-	4
	Other		-	5
2.	Yes		-	1
	No		-	0
3.	Most days of the week		-	1
	Once or twice a week		-	2
	2 or 3 times a week		-	3
	Less than once a month		-	4
	Never		-	5
4 5.	tick		-	1
	blank		-	0
6.	Strongly agree		-	4
	Agree		-	3
	Disagree		-	2
	Strongly disagree		-	1
7.	Yes		-	1
	No		-	0
8 9 10.	Strongly agree		-	5
	Agree		-	4
	Uncertain		-	3
	Disagree		-	2
	Strongly disagree		-	1
11.	Ranking:	first	-	1
		second	-	2
		third	-	3
12 13.	Yes		-	1
	No		-	0
14.	Ranking:	first	-	1
		second	-	2
		third	-	3
		fourth	-	4

QUESTIONNAIRE:RAW DATA

grade	CUS	PUS	CSWD	PSWD	LASER
3	1	1	1	1	1
1	1	1	1	1	0
1	1	1	1	1	0
1	1	1	1	1	0
1	1	1	1	1	0
3	1	1	1	1	0
4	1	1	1	1	0
3	1	1	0	1	0
4	1	1	0	1	1
3	1	1	0	1	1
2	1	1	1	1	1
1	1	1	0	1	1
1	1	1	0	1	1
2	1	1	1	1	1
3	1	1	1	1	0
1	1	1	1	1	0
4	1	1	1	1	0
3	1	1	1	1	0
3	1	1	0	0	0
3	1	1	0	0	0
3	1	1	0	0	0
2	1	1	1	1	1
3	1	1	1	1	0
1	1	1	1	1	1
3	1	1	1	1	1
2	1	1	1	1	0
3	1	1	1	1	0
2	1	1	1	1	0
2	1	1	1	1	0
2	1	1	1	1	0
2	1	1	1	1	0
2	1	1	1	1	1
1	1	1	1	1	1
3	1	1	1	1	1
3	1	1	1	1	0
3	1	1	0	1	0
3	1	1	1	1	0
2	1	1	1	1	0
2	1	1	0	1	0
2	1	1	0	1	0
2	1	1	0	1	0
1	1	1	0	1	0
1	1	1	1	1	0
1	1	1	1	1	0
2	1	1	1	1	0
2	1	1	1	1	0
4	1	1	1	1	0
2	1	1	1	1	1
2	1	1	1	1	0
4	1	1	1	1	0

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4	1	1	1	1	0
3	1	1	1	1	0
3	1	1	1	1	1
1	1	1	1	1	0
2	1	1	0	1	0
3	1	1	0	1	0
1	1	1	1	1	0
2	1	1	1	1	0
3	1	1	1	1	0
1	1	1	1	1	1
4	1	1	1	1	0
2	1	1	1	1	0
1	1	1	1	1	0
3	1	1	1	1	0
2	1	1	1	1	0
2	1	1	1	1	0
2	1	1	1	1	1
2	1	1	1	1	1
1	1	1	1	1	0
2	1	1	1	1	0
3	1	1	1	1	0
4	1	1	1	1	0
1	1	1	1	1	0
2	1	1	1	1	1
2	1	1	1	1	0
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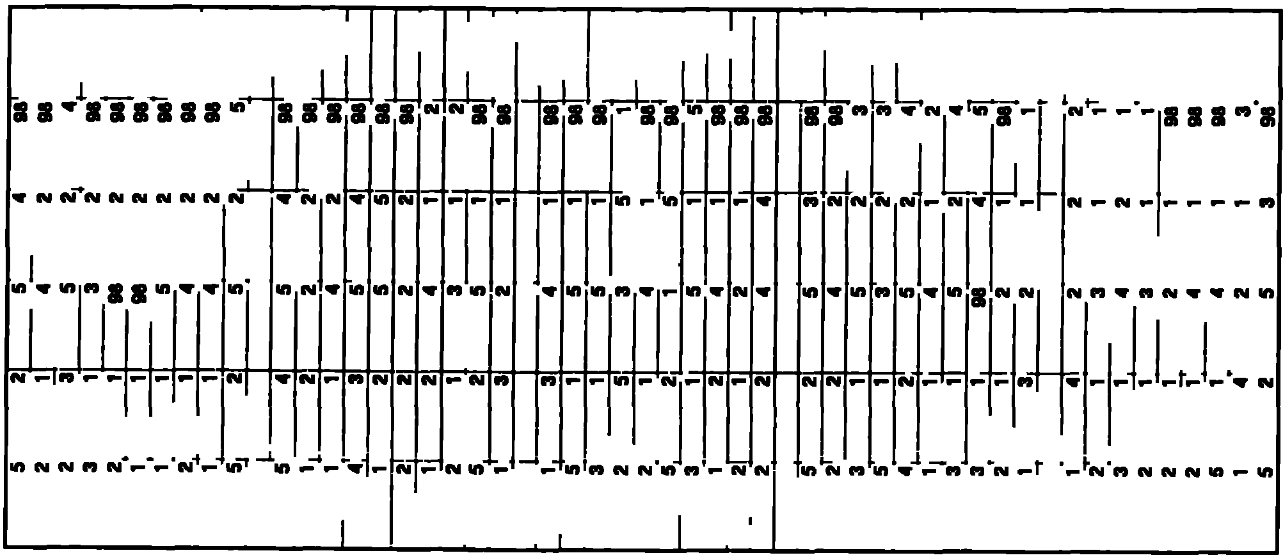

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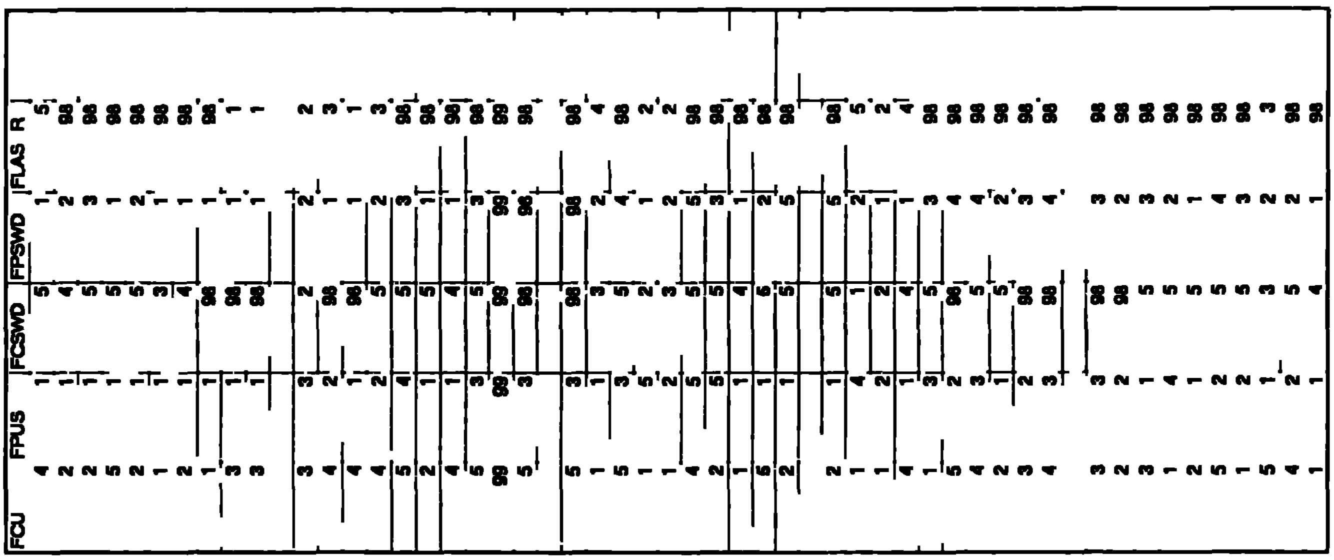

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6 [illegible]

BCUS HBPUS HBCSWD PSWD HBLAS R

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Page 13

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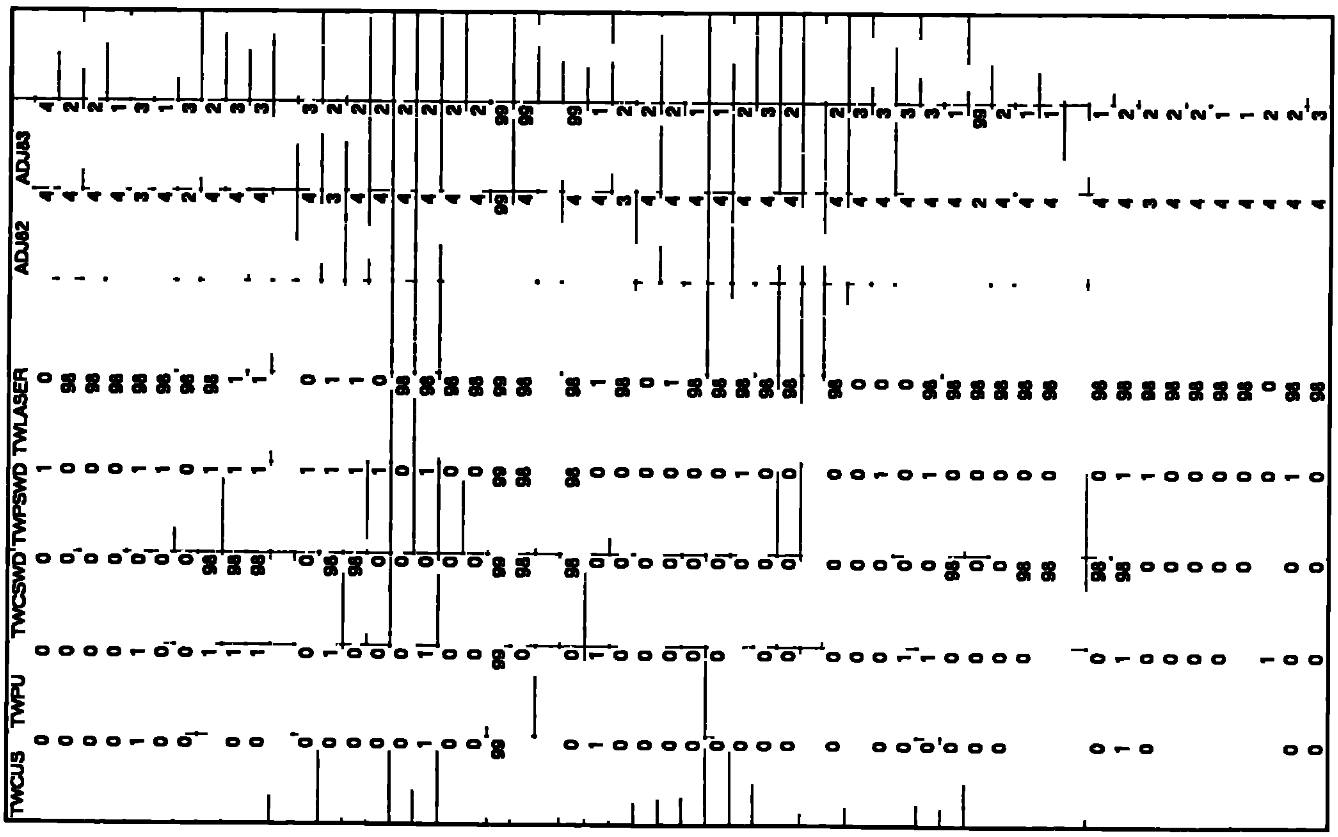

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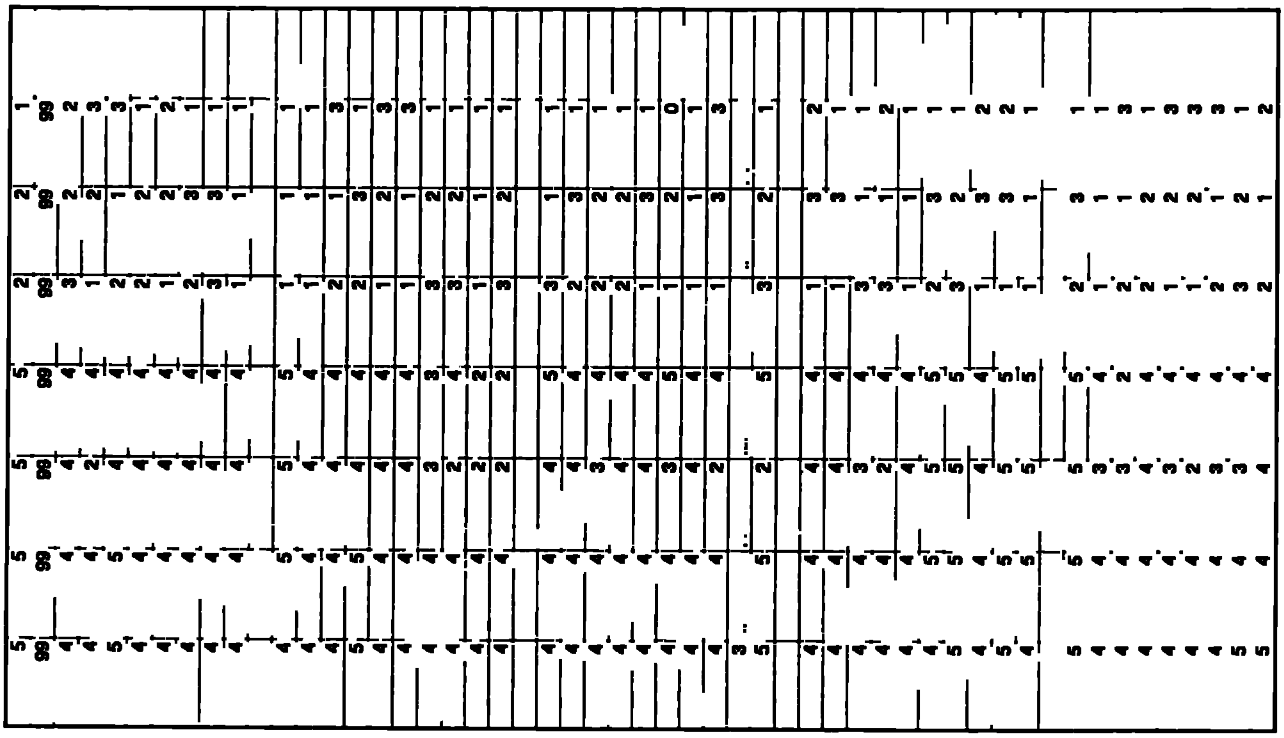

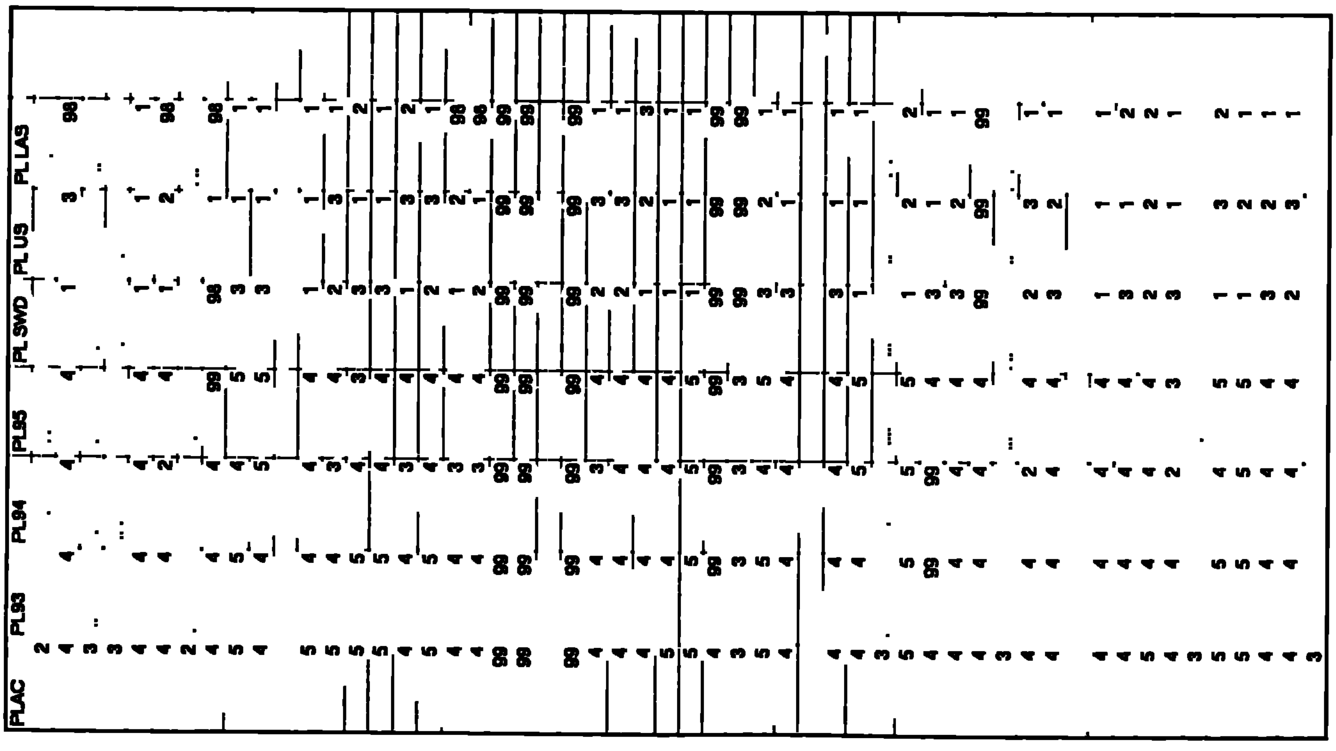
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PL LAS

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QAIRE 10

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QAIRE 10

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APPENDIX 11

SAMPLE CASE HISTORY
BRUISING OF THE QUADRICEPS MUSCLE

1. male
2. age: 42
3. height 5ft 9 in
4. weight: 10 stone
3. office worker
4. sedentary job at factory; little walking about during the day.
5. paper work, VDU work
6. considerable pressure to process material quickly and accurately
9. married
10. three children; all at secondary school
11. wife works part time as shop assistant
12. recently bought council house
13. hobbies: gardening, films

14. struck a direct blow by cricket ball
15. hit in mid quadriceps muscle
16. LEFT LEG
17. assisted indoors; rested with foot up; slept badly that night
18. awoke to find that leg swollen; bruising around knee joint

19. attended casualty
20. X-ray: normal
21. given elbow crutches; taught partial weight bearing gait
22. advised to elevate / rest leg
23. to await physiotherapy appointment

24. arrived at clinic 10 days after injury
25. driven to appointment by wife; unable to drive due to injury.

26. enter clinic on elbow crutches
27. minimal weight bearing
28. sit with leg extended in front of him - knee flexed to 30^0 approx
29. difficulty undressing and getting onto couch

30. bruising - mainly around knee joint; purple , yellow colour
31. swelling; around knee joint; small volume
32. hard swelling in region of injury
33. skin colour; mottled but normal
34. temperature - warm over quads region; knee joint
35. no scars, etc

36. no tenderness felt about the knee joint, ankle fine
37. tender around and over injured site (size of normal cricket ball)
38. 'firm' over injured site

39. dull ache all the time
40. increases on movement
41. reluctant to move
42. pain wakes him at night
43. pain increases slightly during the day

44. active range: hip full; normal
45. ankle full; normal

46. knee - flexion limited by 30o
- extension limited by 10^0

47. all movements limited by pain and tightness

48. passive range: hip and ankle as above

49. knee - flexion limited by 30^0 as above

50 - extension full

51. strength - static - hamstrings equal to other side (scale 4)

52. quadriceps little attempt to contract; due to pain

53. strength - active - not attempted as pain was inhibiting active movements

54. no neurological symptoms

55. drugs - nil

56. general medical conditions - Nil

57. anxious; worried about knee involvement

58. tired due to broken nights

59. afraid of weight bearing

60. not keen to return to work as doesn't like job

CASE HISTORY I:
SOFT TISSUE LESION OF THE HAND

1. male
2. age: 28
3. height: 6 ft.
4. weight: 15 stone
5. construction worker
6. presently in work
7. semi-skilled
8. little work available in his locality due to recession
9. mainly brick work - lifting, handling, building, shifting sand, cement
10. married
11. two small children
12. wife not working outside the home
13. hobbies: football, pubs, TV.
14. plays football every Sunday; helps run/ coach local boys football club.

15. laceration to hand
16. due to falling on masonry, building debris; no glass or metal
17. fall forward onto outstretched hand
18. four days ago
19. no other injuries

20. occupational injury - accident at work
21. self employed
22. no insurance

23. ragged laceration
24. contained sand and dirt

25. lesion on LEFT hand
26. right hand dominant
27. 'y' shaped lesion on palmer aspect

28. no first aid at work
29. taken directly to casualty by colleague
30. debrided, cleaned in casualty
31. X-rayed
32. sutured - 8 present along line of lesion
33. dressed
34. given 5 day supply of oral antibiotics
35. pain killers as required; paracetamol
36. advised to rest, use as possible,
37. given appointment for physiotherapy
38. checked re tetanus
39. appointment to remove sutures with GP in six days

40. no fractures
41. no foreign bodies
42. no tendon lesions
43. no infection presently apparent

44. sutures - pulling slightly
45. oozing - clear exudate
46. bruising over thenar and hypothenar eminences
47. small haematoma

48. swelling: mainly on dorsal aspect and fingers;
49. soft texture, mobile
50. taut due to increased volume
51. increases towards evening
52. increases in dependent position
53. circulation: normal capillary return where possible to see
54. inflammatory signs - slightly warm, red in region of sutures
55. skin colour - blotchy; 'pink and white'
56. skin condition - sweaty, stretched but normal texture
57. no neural involvement; no pins and needles etc
58. some numbness due to swelling

59. range of movement: neck, shoulder and elbow full range
60. wrist: flexion - mid 3 4 of normal
61. extension - mid 3/4 of normal
62. ulna deviation - normal
63. radial deviation - normal
64. fingers: flexion / extension - mid 2/3 or normal
65. thumb: mid 2/3 of normal
66. range slightly greater in the morning; more restricted in evening
67. gradually becoming stiffer each day
68. movements limited by pain and swelling
69. no ligamentous shortening

70. muscle strength - not tested as too painful

71. pain: mild throbbing at rest
72. 'tearing' pain on all movements producing stretch
73. movement results in increase in pain
74. at rest, at best intensity on 10 point scale is 3
75. on movement, at worst intensity on 10 point scale is 7
76. better in the morning
77. better than when first done
78. better in elevation

79. functional problems: unable to grip satisfactorily, all grips affected
80. not too big a problem as L hand
81. reluctant to use for eating etc

82. handicap: unable to work

83. anxious to return to work; afraid of losing job
84. blames firm for accident
85. unsure whether to sue for compensation as afraid of loosing his job
86. hand held up in front of body, protective position
87. allows therapist to touch injured hand
88. verbal warning about pain g ven by patient
89. attempts to use hand as far as possible but afraid sutures will tear
90. willing to attend treatment frequently until able to return to work
91. expects to return to work very rapidly

92. no previous physiotherapy treatment
93. no general medication
94. no other general diseases
95. no previo s injuries to the hand, arm, neck

CASE HISTORY II:
LATERAL LIGAMENT INJURY OF THE ANKLE

1. female
2. age: 78
3. housewife
4. height: 5' 2"
5. weight: 12 stone
6. sedentary life style - housework, cooking, visit daughter weekly
7. independent; able to shop etc
8. husband retired accountant, age 76, part time job until 6 months ago
9. not happy to have him around the house all the time
10. two children
11. daughter married with two adult children; husband unemployed
12. son divorced; never sees grandchildren
13. hobbies: knitting, TV
14. house bound since injury; visited daughter - went by car

15. lives in house with stairs
16. loo upstairs
17. handrail on one side only - right as going up
18. loose rugs, some worn carpets

19. injury to RIGHT ANKLE
20. three weeks ago
21. attended casualty
22. X-ray taken
23. stick (double) given
24. tubigrip (toes to knee) given
25. advised that physiotherapy appointment would be sent
26. advised to rest, elevate and gently move part

27. injury tripped over paving stone
28. fell to the ground
29. foot under body
30. helped into shop
31. ambulance called
32. blaming the council for poor condition of roads

33. recurrent injury
34. original injury: slipped in icy weather, foot under body
35. eight years ago
36. inversion injury
37. was unable to take weight on it
38. X-ray (no bony damage)
39. physiotherapy for 6 weeks ice, US, exercise, foot class
40. residual problems: no pain but feeling of instability
41. often gives way (1-2 times per month)
42. not usually very painful
43. rest and a crepe bandage for a couple of days

44. since injury: spent most of the time sitting with foot on stool (9")
45. husband taken over all the cooking, shopping etc
46. daughter been over to help husband with laundry, cleaning
47. tubigrip both night and day

48. arrives in treatment area wearing tubigrip,

49. single stick
50. taking minimal weight through the foot
51. accompanied by husband
52. stick held on same side as injury
53. in sitting: foot held in relaxed position, no pressure (see diagram)

54. X-ray indicates no bony damage
55. no complete ligamentous tears
56. swelling; dorsum of foot; malleoli obscured; extend 1 3 way up the leg
57. swelling better in the morning; worse in the evening
58. firm swelling, pitting
59. ankle is always slightly swollen
60. bruising: nil; no history of bruising immediately following injury
61. some numbness over ankle and dorsum of foot
62. no pins and needles

63. pain: dull ache all the time,
64. increases on movement (therefore tries not to move it)
65. pain on awaking, slightly better by lunch time, worse again by late afternoon evening
66. night pain; woken some nights
67. pattern of pain as above all the time now; was worse when first happened, more severe, sharp pain
68. general pain aggravated by movement, weight bearing
69. eased by rest, hot baths, crepe bandage
70. pain at worst: 7 on 10 point scale
71. pain at best: 3-4 on 10 point scale

72. skin colour: mottled
73. skin condition: dry, papery, 'stretched'
74. skin temperature: injured foot warmer than unaffected foot; toes cold

75. no scars etc

76. palpation: pitting oedema, thickened texture around joints
77. tenderness over lateral aspect of ankle joint; anterior tibiofibular ligament, talonavicular ligament, cervical and bifurcate ligament
78. reluctant to allow handling

79. proprioception: unable to test for affected leg
80. diminished balance when standing on sound leg

81. active range: hip - normal, equal but limited
82. knee - normal, equal but limited
83. ankle - no inversion
84. minimal eversion
85. dorsiflexion to neutral,
86. plantar flexion 10 degrees (mainly in forefoot)
87. toes: can wriggle normally

88. gross passive movements: hip and knee as above
89. ankle: dorsi flexion to neutral
90. plantar flexion 15 degrees
91. inversion 5 - 10 degrees
92. eversion 10 degrees
93. toes full and normal
94. resistance felt during passive movement
95. mainly due to active resistance, eased as movement repeated
96. some resistance d e to swelling

97. accessory movement - not possible due to pain

98. static muscle work: little pain, oxford scale grade 4.
99. active muscle work: produced increase in pain immediately, grade 3

100. other joints: minimal 'arthritic' changes in all joints of both lower limbs; similar levels of range on both legs; no pain elicited

101. shoes: affected foot - loose slipper worn
102. : unaffected foot - court shoe, 1" heel; prefers to wear 2" heels

103. function: reduced; not able to shop, cook, difficulty with stairs
104. handicap: minimal ... quite enjoying help!

105. very anxious
106. little confidence in foot
107. worried about pain, unwilling to allow procedures which increase pain

108. medication: taking paracetamol as often as she thinks she needs it - about five times a day

109. mild arthritic changes in lower limb joints, some neck pain
110. takes paracetamol or nurofen as required;
111. blood pressure problems
112. controlled by use of diuretics

APPENDIX 12

INFORMATION SHEET:

ELECTROTHERAPY IN THE MANAGEMENT OF SOFT TISSUE LESIONS: SELECTION OF TREATMENTS

We are currently undertaking an in-depth study of the use of electrophysical agent in clinical practice and the factors which govern the selection of treatments for individual patients, We have received enormous support from clinicians throughout the country as we have examined the use made of ultrasound, continuous and pulsed shortwave diathermy and laser in the treatment of soft tissue lesions and are extremely grateful to those therapists for their help. We are now about to examine in detail the ways in which experienced physiotherapists select specific treatments for their patients.

A wide variety of soft tissue lesions are treated by physiotherapists, and clinicians make use of a number of different types and combinations of treatments in their management of such injuries. Treatment programmes often incorporate both active and passive techniques such as exercise, passive stretching, mobilisations, strapping and the use of electrophysical agents.

Little, however, is known about the criteria which govern the ways in which physiotherapists select particular treatments packages for their patients, though it is clear that experienced clinicians develop considerable skills in this area. A detailed examination of the processes used by experienced clinicians is therefore necessary to provide information about these skills. This information will help us to provide students and less experienced clinicians with guide lines for the selection of electrophysical agents in clinical practice.

The procedure we are using in this study is a modified version of that of Kassirer and Gorry (1976) and I will be asking participants to talk through two case histories with me. This will involve participants in taking the case histories of two hypothetical subjects with soft tissue lesions. Initially, the patient's age, sex and type of lesion are provided; additional case material will then be given in response to questions. The participant will be asked to 'think aloud', verbalizing all their thoughts as they collect information about the patients. Both case histories will describe commonly treated conditions and will not include rare or 'trick' elements!

The interviews should take no more than an hour. I shall be happy to come and see you at your place of work or you would be welcome to come to Kings College in the Strand, London; your travel expenses would, of course, be paid. All data collected will be treated in the strictest confidence; you will not be identified as an individual in any of our work as it is the group as a whole in whom we are interested.

Please feel free to contact me at the address below at any time if you have any questions or want further information

* Kassirer J P and Gorry G A (1978) Clinical problem solving: A behavioral analysis. Annals of Internal Medicine, 89, 245-255.

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APPENDIX 13

ELECTROTHERAPY IN THE MANAGEMENT OF SOFT TISSUE LESIONS
SELECTION OF TREATMENT

VERBAL INTRODUCTION

Thank you so much for agreeing to take part in this study! I know you have had our information sheet but let me tell you a bit more about what we are doing.

1. We have just finished looking at the use made of US, SWD and laser by therapists across the country; this has helped us see what people are using and given us some ideas about the factors that are affecting their selection. What it hasn't been able to tell us is HOW people are making their selection. There is a clear need to find out how experienced clinicians select treatment in order to pass this information on to less experienced student and staff.

Example: Higgs and Butler in Australia have examined the ways in which experienced physiotherapists select mobilisation techniques for the treatment of the spine. They are using this information to help train student and novice therapists and facilitate the development of their selection skills.

2. Clinical experience clearly allows experienced staff to develop considerable skill in the selection of treatments and this is something we would like to tap. There are problems in trying to do this; experts often say that they 'just know' what to do. They often are unable to explain directly how they arrive at a decision - so we can't just ask you how you decide!

3. There are many ways of looking at selection processes used. Patients may and staff may be videoed as they work together; sometimes staff are asked to talk through their assessments or treatments while seeing the patient and on other occasions practitioners are asked to discuss their thoughts and reasonings afterwards. Sometimes actors may be used to simulate patients so that more than one therapist can assess or treat the 'same' subject. There are a variety of problems with these methods as you can imagine.

4. As we said in our information sheet, the method we would like to use involves the use of two case histories. These have been developed on the basis of interviews with experienced clinicians. What I would like you to do is take the case history of these two subjects, telling me all you are thinking as you go along.

5. I would like to tape the session as taking notes spoils the flow and provides an incomplete record. As I said in your letter, you will not be identified in any of the work resulting from this interview and the tapes will be destroyed as soon as we have finished transcribing the data.

(Get agreement)

6. LET'S HAVE A DETAILED RUN THROUGH!

I will present you with a 'basic referral'; I will provide you with some initial information about the patient such as 'A lady attends for treatment for an injury to the elbow'.

7. I will then make the following request:

'Please take the history of the presenting problem and develop a plan of immediate physiotherapy treatment. I would like you to 'think aloud', telling me everything you are thinking as you collect information from me'.

8. There are a series of stages - like this :

a. I would like you to imagine that you are examining this patient. I will simulate the patient, though only verbally! I will provide the answers to the questions you might wish to ask about the condition as you take the history.

Please make your questions as specific as possible; general questions such as 'what functional problems does this patient have?' will not be answered.

b. Please 'think aloud' all the ideas and thoughts you have as you are taking these histories.

c. When you receive the information you are seeking I would like you to tell me what you think as you gather the material.

d. As soon as you begin to think about any specific or general types of treatment for this subject I would like you to tell me about it.

e. Don't feel you have to select a specific type of electrical treatment - or even ANY type at all! We are interested in how you reached your decisions.

f. When you have enough information to allow you to select your treatment for this subject, please summarise you treatment plans.

One thing you will have to remember is that this is a simulated case history; you may need to ask me about things that you would normally be able to see for yourself. There may also be occasions when information will be unavailable to you.

9. Remember ... normal practice should be followed as far as possible. We want to know how you usually do it!

10. Show example of transcript and discuss what is happening; note that the example is from a diagnostic study

11. Practice case history taking and 'thinking aloud' through the use of a sample case history; to be terminated as soon as the subject and interviewer are content that the format of the interview is clear.

12. Provide paper to make notes of history taken; retrieve at the end.

Sample 1.

Second Subject – Women's Suits

INT: Just go ahead and talk.

SUB: Well another question would be if a salesgirl wants to help me or something and I don't usually like to have help until I have picked out the items I want – now can I tell her this there or do you care in any way or can I just go ahead and do whatever I want?

First shopping trip

DATE: May 23rd

Shopping companion – Zenna Z

SUB: Casual Corner looking at suits now. Here we are. Ummm. I guess all this is size 10s. Ohh I don't think the color pink, too frilly looking, straight skirt. White is impractical. Pink again, straight skirt, bows, not much – I don't like sleeveless things. The color's nice, a greenish color. An orangey yellow knit, sleeveless. Impractical too. White again – same thing. Uhh light blue kind of attractive knit suit but straight skirt – no good. Exact same style as the blue, but straight skirt. A pink straight skirt same style. Oh a print. I like the print color. It's a pinky reddish color. A-line skirt. Very attractive $14.99 – I can't afford it. Yellow is very similar to the pink and blue. Knit straight skirt. I am not interested in straight skirts. Ohh, here is one like the print of the reddish color. It is a greenish color – A-line skirt – almost the exact same thing – box jacket. Also $15 about. Very attractive. I'll try it on too. That's just like the suit I have on isn't it? A yellow. It's a jersey knit sleeveless – sort of a very tiny top. Not at all practical for school. Oh, here is a sort of beige, well very l ght eggshell suit with sort of leather piping very attra tive. Box jacket effect. I l ke the light color. I like the A-line skirt. I like the p p ng a lot. I'll try that on too. Let me check the price first.

INT: It's on the back

SUB Size 10. $22 99. That's $23. That's still all right Uhh Sort of a flowery green and purple and p nky thing Too loud looking for school and I am interested in s hool clothes A p a d s t ol muddy c ored kind of d ab l king but s the sty e I l ke AAA, a box ja ket suit a in, A line sk rt s rt of a muddy color alm t but I think it is k nd of attr t tive I d like to try th s on too It s n t fr l y It's ta or cut Here is the g een su t a 'n

(Haines, 1974)

Sample 2.

RESPONDENT: This is a 57-year-old woman who is admitted to the hospital with the chief complaint of nausea, vomiting, abdominal pain and frequency of urination.

CLINICIAN: First I'm going to ask some questions about the character of her urinary stream; I'm thinking in terms of *infection in her lower urinary tract*. Did this patient notice any blood in her urine?

RESPONDENT: No, she didn't.

CLINICIAN: That she didn't have gross haematuria makes me turn away from one possibility - that she might have *passed a stone in association with infection*. She might have had a *haemorrhagic cystitis* but that makes it unlikely, just at first cut. You said that she had frequency - did she have pain on urination? I'm asking that in terms of also *inflammation of the bladder*.

RESPONDENT: She did complain of some burning on urination.

CLINICIAN: Now again continuing along the infection line, I'm going to ask whether she had a fever just in terms of *generalized infection*.

CLINICIAN: Did she have any history of high blood pressure? The reason I'm asking that question is that in association with certain kinds of renal insufficiency, hypertension is a very common feature.

RESPONDENT: No, she didn't.

CLINICIAN: The answer to that question leads me away from something like chronic glomerulonephritis as causing her renal insufficiency. It's consistent with chronic pyelonephritis. You could have hypertension or no hypertension.

(Kassirer and Gorry, 1978)

APPENDIX 14

Case I. 1H

*: right .. when you're ready .. 'A man attends for treatment for an injury to the hand'

'Please take the history of the presenting problem and develop a plan of immediate physiotherapy treatment. I would like you to 'think aloud', telling me everything you are thinking as you collect information from me'.

1: OK .. so I would ask him when he sustained the injury to his hand
*: he sustained the injury four days ago
2: and what was he doing?
*: he fell onto some concrete .. broken rubble
3: was he falling onto an outstretched hand?
*: yes, he fell forward onto an outstretched hand onto this building material
4: so .... if he fell on an outstretched hand he would have been tense ..
5. a fracture possibly ...
6. if he'd sort of rolled onto it, it is more likely to be soft tissue injury ....
7. he has seen a doctor?
*: yes , he went to casualty.
8. he went to casualty?
9. so has he had an X-ray?
*: he had an X-ray ...
10. any fractures?
*: there are no fractures
11. OK ... well, so I know already that it is not a fracture ....
12. it's a soft tissue injury ...
13. probably a contusion or ligament injury ...
14. and the bruising and swelling ...
15. so from a physio point of view we can do quite 1 lot for him ....
16. I'd ask him where it was painful
*: his hand is very painful .. on the palmer aspect .. over the thenar and hypothenar eminences
17. and is it localised to that area?
*: yes
18. left hand .. right hand?
*: left
19. and his dominant hand?
*: his right hand is his dominant hand
20. so he can get around and dress himself ...
21. he won't be incapacitated ...
22. but it's still an important injury around the thumb and the index finger
23. it's just not as important to get him back to normal as quickly as possible if its not his dominant side
24. I'd have a look to see if it was swollen ..
25. is it?
*: yes, its very swollen ... it's particularly swollen on the dorsum ... less so on the palmer aspect
26. restricted to the hand or radiating?
*: it's restricted to the hand ... not really much radiating above the wrist
27. fingers ... thumb?
*: yes, they are swollen
28. can he flex his fingers?
*: he can flex his fingers through the middle 2/3 of their normal range
29. what colour is his hand?
*: it's blotchy; pink and white ... with some redness around the lesion
30. no blue fingers ...
31. no whiteness of the fingers?

*: no
32. right ...
33. again I would be extremely wary if it was looking a bad colour ...
34. circulation ...
35. if the colour looked normal ...
36. I'd expect it to be swollen if he'd hurt it badly
37. but if the colour was normal
38. and the circulation ...
39. then I'd look at it very closely
40. has he got any support bandage or anything?
*: he has a light dressing over the top of it but no support
41. is the skin torn ...abrasions?
*: yes, the skin is torn
42. right ..
43. has he put any medication on it ... for it?
*: not on it .. but he is having antibiotics
44. antibiotics ....
45. I would ask him then what sort of work he did
*: he is a construction worker
46. a construction worker ... so he will need both his hands
47. is he self employed?
*: he is self employed
48. he will need to get back to work quickly ... and ...
49. I'd ask him whether he had ever injured that arm at all
*: no
50. no previous injuries ....
51. and the right hand?
*: none at all
52. I'd ask him whether he was at work when it happened
*: yes, he was at work; he fell while he was at work
53. maybe a compensation problem ..
54. or dangerous for him in this trade ...
55. I'd probably ask how he fell ...
56. it wasn't a blackout or any thing like that was it?
*: no ... it was tripping over .. blocks ... rubble... there were bits in the way
57. right ...
58. so I'd probably tell him he needed to be more careful about work
59. I think that if it was at work and he was self employed I would probably warn him that this kind of thing is dangerous ...
60. I haven't asked what age he is yet.
61. how old is he?
*: he is 28
62. 28?
63. OK ...
64. he is a young man then. ...
65. whether he had a dizzy attack ...
66. there would probably be something else going on which needs to be investigated ..
67. not a simple slip and a fall ...
68. and I would probably give him some advice on safety at work
69. and say that he's got to keep his eyes on what's around...
70. he might be working in a very dangerous area ..
*: right
71. I would now ... I'd ask him what sort of activities were normal for him ...
72. he s got a heavy job anyway ...
73. he needs his hands ...
74. does he do any sport ....
75. does he play football?

*: yes ... football ... and pubs and TV!
76. so nothing with terribly fine movements necessary?
*: no
77. no snooker or anything like that?
*: no .. nothing like that
78. so .. for his work he needs his hands
79. I would now examine him ..
80. take his shirt off ...
81. take off all his top clothes
82. and have a look at every thing
83. the most likely thing is that it would disturb his neck ...
84. I would probably sit him on a couch
85. and check his neck movements ...
86. I'd lie him down to examine him ...
87. I prefer examining the arm in lying ..
88. they relax better
89. I can examine the shoulder and elbow
90. you never injure anything in isolation
91. a fall on the outstretched hand could give him a neck injury ....
92. certainly a latent neck injury or if he had an old neck injury that could be stirred up ...
93. he could jar his shoulder joint ...
94. could upset his elbow ...
95. and check shoulder movements to see if there was any muscle weakness
96. or inability to raise the arm above the head.
97. are they OK?
*: he has no problem with respect to his neck or his shoulder .. and has no previous history
98. so not those ...
99. fine ...
100. I would lie him down
101. and check his hand
102. I'd examine it for colour temperature and the amount of swelling.
103. colour?
*: it's blotchy ... white and pinkish red... the kind of pinkness you get with swelling.. no blueness
104. temperature?
*: temperature .. slightly raised over the injured area but nothing excessive
105. with the abrasion you are going to have to be particularly careful about local infection ...
106. even with antibiotic cover
*: yes
107. are the abrasions really bad?
108. are they healing up now ..
109. are they pussy?
*: they are oozing... but it is a clear exudate... it's in the process of healing
110. how deep ..
111. are there sutures?
*: yes .. there are sutures present
112. sutures ... they are coming out when ... in 7 days?
*: yes in 6 days ... he's going back to this GP to have them out
113. how may sutures?
*: there are eight
114. and where are they ..
115. on the thenar eminence ...
116. where's the injury?
*: yes ... the injury is approximately here (diagram 1)
117. the sutures are all along that?
*: yes
118. .... so that is going to affect his mobility quite considerably ..
119. .. it's cut right across the muscle .... the opponens ...

120. any sort of compression is going to be painful ...
121. stretching it out is going to be painful ...
122. very important to get his mobility back as quickly as possible ....
123. reduce the swelling and get the scar mobile ....
124. it all depends on how he heals ...
125. some people heal appallingly badly ...
126. you said there was swelling on the dorsum as well as the palmer aspect?
*: yes it's quite puffy
127. the fingers are tight?
*: yes
128. I would check the mobility of all the fingers to see what range he had got
129. and decide whether that range was affected by bruising to the individual fingers
130. or whether it was just swelling that was restricting the range .... 131. so?
*: right ... he has actually got limited movement ... he's not keen to move ... it's painful .. so what he is prepared to do is gross movements .. he can move through the middle 2 3 of a normal full range of finger and thumb flexion / extension
132. so its going to be quite difficult to examine him ...
133. I'd try and passively examine him ....
134. to see if anything gives ary more trouble ...
135. and whether he had bruised any where else
136. and then I'd do thumb range ....
137. what gross thumb range there is in the thumb?
*: the thumb movement are very similar to the fingers .. about 2/3 of normal range
138. and passive movements .. what are they like ..
139. can I achieve a greater range than the active?
*: yes .. you can achieve almost a full range provided you can get him into a comfortable position .. get hold of his hand .. avoid stretching the injury too much
140. so it sound as though it's soft tissue problems that are limiting his movement ..
141. probably the swelling to ... and the pain ..
142. I guess that the stretch is causing a lot of problems ..
143. so ... I would treat him at this stage ...
144. I think I would treat the lesion with laser ..
145. not US ..
146. you couldn't use a contact method
147. and water baths would be inappropriate with the open lesion ...
148. you might induce an infection ...
149. laser is a non-touch technique
150. and I've had very good results with it ..
151. 1 joule at 2 or 3 points I think ...
152. along the line of the injury ...
153. I'd use it around the injury to try and promote healing ..
154. reduce the scar formation ..
155. rather like US really ...
156. I could use PSWD
157. but I think with a small area like this it wouldn't be so easy to apply ...
158. lots of gentle exercise in elevation ..
159. I might do some gentle effleurage
160. but I'm not so sure ..
161. the patient can do that for themselves if you show them how to ...
162. and I think exercise will really be better ..
163. lots of advice ..
164. keep his hand up ..
165. rest but not too much ...
166. he could ha e a sling for when he goes out ..
167. that would stop it hanging down at his side ...
168. I'd explain that it would hurt
169. and that was normal especially with the sutures in ...

170. but that was OK ..
171. he could still carry on with the exercise ...
172. do things around the house
173. I'd tell him to keep it clean ..
174. dry ...
175. not knock it ..
176. or dangle it down by his side ..
177. and I'd see him daily

*: that's fine .. thank you very much indeed.

<u>Case II. 6A</u>

Right .. when you're ready ... 'A woman attends for treatment for an injury to the ankle'

'Please take the history of the presenting problem and develop a plan of immediate physiotherapy treatment. I would like you to 'think aloud', telling me everything you are thinking as you collect information from me'.

1. right
2. can I ask how old this lady is?
*: yes, she's 78
3. and which ankle?
*: right ankle
4. and she's obviously retired
*: yes, she's a housewife at home
5. is she living on her own?
*: no, she's got a husband around at home
6. and is she sort of reasonably active still?
*: not very, really, she potters around the house normally .... goes out to see her children perhaps once or twice a week but not a great deal ..
7. right
8. can you tell me when the ankle was injured?
*: it was 3 weeks ago
9. and what happened?
*: she just slipped on the pavement and fell
10. and could she remember how she fell?
*: her foot was underneath her
11. so like an inverted injury?
*: yes .. she just slipped and her foot went underneath her
12. right
13. and could she walk on it afterwards?
*: minimal ... it was very uncomfortable, she didn't want to take any weight on to it
14. so did she...
15. what happened then
16. did she go to casualty
*: yes, her husband helped her up and they went into a shop .. an ambulance came and they went to casualty and they looked at it
17. I'm just trying to find out really the age and function of the lady ...
18. she's not particularly active
19. she's quite elderly ....
20. so really the most important thing here is that we are going to aim for functioning as quickly as possibly
21. it's not going to matter that she has absolute full range of movement
22. the thing is to get her mobile and home ...
23. obviously I would then want to find out whether...what sort of an injury she's had

24. real inversion sprains to her ankle
25. she's gone to casualty...
26. was she X-rayed?
*: yes, X-ray and no injuries, no bony injuries
27. OK
28. and did they give her crutch s or anything?
*: they gave her two sticks to use, yes
29. and was she putting weight through the foot?
*: a little, very reluctant to put weight through but they didn't say she couldn't
30. and has she been home and hobbled around at home for 3 weeks?
*: that's right, she's been mainly sitting around being looked after for 3 weeks, but she's been at home
31. so, is it her GP that's sent her now?
*: the hospital said they would process it and its just taken this length of time for before you've actually seen her
32. and has she got here today under her own steam?
*: well her husband has brought her in the car
33. and has she got any pain at all?
*: yes, it's very painful ... all very uncomfortable
34. just the foot?
*: the foot and the ankle .. and there is a general leg ache beginning
35. OK
36. is the pain in the foot and ankle to one side
37. or is it just generally the whole foot and ankle?
*: it's mainly where she hurt it on the outside, but it's the whole foot and ankle and its generally uncomfortable
38. and is there any swelling?
*: yes, it's swollen
39. and is it just the foot that's swollen
40. or is it below the knee?
*: it extends about a 1/3 of the way up the lower leg ....
41. so she's saying that the pain is a big problem
42. and also swelling again is a big problem
43. and I would assume that is due to her sitting for 3 weeks doing absolutely nothing ...
44. she's saying her hip's hurting
45. but I would assume it's as a result of her walking poorly ...
46. so that's probably something to look at a later date ...
47. obviously the fact that she's had an inversion injury
48. so you'd automatically think ... lateral ligament sprain ....
49. but it's just as well to check that there are no fractures
50. she's been X-rayed
51. she's has been sent home with two sticks
52. which I'm quite surprised about
53. I would have thought she would at least need crutches. ...
54. and it's appalling that its taken 3 weeks to see her
55. she should really have been seen from day 1 ...
56. obviously they didn't have an A&E procedure with their physio department
*: no
57. and is the swelling quite boggy?
*: well it's mixed because she's normally...her foots a little bit swollen
... and thickened, but it's really quite firm .. pitting oedema
58. is it more swollen than the other side?
*: yes
59. does she get the pain .... is the pain there all the time
60. or does it come and go?
*: it's there all the time but it's certainly worse after the day .... during the evening it gets really uncomfortable ... a bit better in the morni g

61. does it get worse when she's walking on it?
*: yes, she doesn't like walking on it
62. if she had to give the pain a number out of 10 if 0 were no pain 10 absolutely agony, what would she give it?
*: first thing in the morning its probably about 5, towards the end of the day its probably about 7 I would think
63. has she had any recent operations or illnesses
*: no
64. any tablets ... medication?
*: she's on various tablets
65. what tablets is she on?
*: she's on diuretics ... she's got blood pressure problems ....
66. any other problems?
*: she's getting a little bit of mild arthritis in her lower limb joints .. and she's over weight
67. and is she on any tablets for that
*: no, she's takes paracetamol whenever she feels its appropriate but
68. right
69. she's not taking any extra tables as a result of this injury?
*: yes, she's taking quite a bit of paracetamol whenever she thinks its appropriate which is about 5 times a day
70. has she ever taken steroids?
*: no, she hasn't
71. any anticoagulants?
*: no
72. and you say she's quite overweight?
*: she is, she's little and she's round
73. normally she doesn't walk with any sticks or anything?
74. she's normally fully weight bearing?
*: she's normally fully weight bearing, yes
75. OK ...
76. the picture I get now is a typical 78 year old really
77. bit overweight
78. bit of a heart problem
79. swelling in her ankle
80. probably a bit of heart failure ...
81. generalised pains really ....
82. painkillers ...
83. she's obviously quite a lot worse because she's increased the number of painkillers she's taking
84. other than that she's reasonably fit for her age I suppose ...
85. has she got a pacemaker?
*: no
86. has she taken any tablets today?
*: yes, she always takes some as soon as she wakes up and she took some before she came out because she thought it would probably start to bother her
87. has she injured her ankle before?
*: yes
88. similar sort of injury?
*: yes, she originally slipped over on an icy road and injured it really quite nastily
89. when was that?
*: that was about 8 years ago something like that
90. and did she recover fully from that?
*: well, its never been quite the same and she goes over on it fairly frequently, probably once or twice a month now, but its not particularly painful. It just goes over and goes under her
91. OK ...
92. so, the problem started 8 years ago ...
93. if it keeps giving way under her she probably has instability
94. and lack of proprioception ...

95. so it's going to be quite important to try and rehabilitate that
96. and stop it from happening again ...
97. now I want to look at her ankle
98. she's 78
99. she's a little bit frail
100. so really I just want to ...
101. it's an ankle problem
102. I want to look at her ... observe her ankle first,
103. and then really home in on the actual side and foot and ankle really
*: right, OK
104. so, on observation, you have already said that the foot and ankle are quite swollen up to about mid calf?
*: yes
105. is there any bruising at all still?
*: no bruising, no sign of bruising
106. and is she walking, partial weight bearing on your 2 sticks?
*: that's right
107. does that look laboured?
*: it's very laboured, very slow
108. OK
109. and if we look at active movement of her ankle are they all limited or all...?
*: yes, they're all very limited ...
110. so what can she do?
111. toes?
*: really all she's happy to do is wiggle her toes actively ...
112. ankle?
*: she's not prepared to invert her foot to any extent . a little eversion. She will pull her ankle up to neutral and down about 10 degrees
113. what's limiting that?
114. is it pain?
*: yes, there's a little pain and she's worried about what's happening as well
115. but she can wriggle her toes OK?
*: yes, she can wriggle her toes
116. does she have any numbness, pins or needles or anything?
*: no, no numbness no pins and needles
117. and when I palpate around the lateral malleolus and the lateral side of the foot .... is it painful in any one area or more in the centre?
*: yes, its very specifically painful around the lateral ligaments of the ankle
118. just general or is it more sort of anterior?
*: there's a very sore point anterolaterally ... yes
119. and it's tender to touch is it?
*: yes
120. and does the ankle appear stable?
*: what do you mean by that?
121. well, if we did a stability test...
*: .. she's very unstable
122. OK
123. from that I have got plenty to go on with really
124. all movement very limited
125. tender anteriorly
126. anterior lateral ligaments sprain
127.which is what I would expect with an inversion sprain
128. she has got laxity
129. which is what I would expect again ...
130. the most important thing really is to get her ankle moving
131. and decrease the pain
132. and do a lot of work on her gait really ...

133. so ... on the first day I would teach her some very simple basic active exercises
134. just to sort of ... her dorsi flexion
135. maybe even get her using a belt to stretch her gastocs...
136. get her circling her foot within her pain
137. and warn her that it will hurt a little bit
138. but that's very important that she gets it moving
139. and just pushes it a little bit
140. because she's getting a lot of soft tissue shortening ...
141. I would certainly work on her gait ...
142. not necessarily in all this order
143. but I would think that if she's got that amount of movement
144. and is very laboured walking
145. then 2 sticks really is not enough support
146. and for someone of her age I would suggest she uses something like a zimmer frame
147. and quite possibly until she gets a bit more mobile
148. I would certainly possibly refer her to some community physio ...
149. because all the good we do by her coming up here would just be gone by the time she gets home again ...
150. I would give her advice to keep it up while she's at home up
151. on the pillows preferably ...
152. and for the pain I think I would do ultrasound
153. for the tender pain over the lateral ligament
154. to try and relieve some of the pain
155. and also to try and encourage the scar tissues to align
156. and possibly if it's very swollen, very thick and boggy I might even consider using a flowtron
*: right
157. and I think that is about I would do at this stage
*: very many thanks .. that's fine

APPENDIX 15

Cues elicited for case history I in traces 1H-9H

CUES	1H	2H	3H	4H	5H	6H	7H	8H	9H	ttl
occupation	X	X	X	X	X	X	X	X	X	9
time since injury*	X	X	X	X	X	X	X	X	X	9
mechanism*	X	X	X	X	X	X	X	X	X	9
lesion	X	X	X	X	X	X	X	X	X	9
prior care*	X	X	X	X	X	X	X	X	X	9
swelling*	X	X	X	X	X	X	X	X	X	9
range*	X	X	X	X	X	X	X	X	X	9
medication*	X	X	X	X	X	X	X	X	X	9
age*	X	X		X	X	X	X	X	X	8
left/right	X	X	X		X	X	X	X	X	8
pain*	X	X	X		X	X	X	X	X	8
dressing/ support	X	X	X	X	X			X	X	7
normal function	X	X	X		X	X			X	6
colour	X		X		X	X	X		X	6
past medical history	X		X		X	X	X		X	6
colour	X		X		X	X	X		X	6
bruising			X			X		X	X	4
temperature	X				X		X		X	4
present general health				X		X	X		X	4
associated problems	X	X	X			X				4
neural signs						X	X		X	3
chief complaint		X	X			X				3
present function							X		X	2
strength			X			X				2
hand posture		X						X		2
temporal patterns						X	X			2
personal details							X			1
referral								X		1
skin condition						X				1
infection				X						1
stiffness						X				1
Total	17	15	18	12	16	23	20	15	21	

Note: * denotes core cues accessed in traces for both case histories.

Cues elicited for case history II

CUES	1A	2A	3A	4A	5A	6A	7A	8A	9A	
time since injury*	X	X	X	X	X	X	X	X	X	9
mechanism*	X	X	X	X	X	X	X	X	X	9
swelling*	X	X	X	X	X	X	X	X	X	9
pain*	X	X	X	X	X	X	X	X	X	9
range*	X	X	X	X	X	X	X	X	X	9
medication*	X	X	X	X	X	X	X	X	X	9
age*	X		X	X	X	X	X	X	X	8
prior care*		X	X	X	X	X	X	X	X	8
gait	X	X	X		X	X	X	X	X	8
present general health	X		X	X	X	X	X	X	X	8
bruising	X	X	X	X		X	X	X		7
weight bearing	X		X	X	X	X	X	X		7
history: foot problems	X	X	X	X		X	X		X	7
left/right	X		X		X	X	X	X		6
home/social situation	X		X			X	X	X	X	6
present function	X		X	X			X	X	X	6
normal function	X	X	X			X			X	5
past medical history	X		X			X	X		X	5
occupation		X	X			X	X			4
colour	X	X	X						X	4
foot wear	X			X				X	X	4
joint stability	X			X		X	X			4
skin condition			X	X					X	3
strength	X		X	X						3
temporal patterns					X		X		X	3
circulation				X					X	2
temperature							X		X	2
skin lesions		X			X					2
neural signs						X		X		2
chief complaint			X					X		2
emotional response	X							X		2
personal details							X			1
fracture	X									1
proprioception					X					1
foot posture	X									1
Total	24	14	23	18	15	20	22	19	21	

Note: * denotes core cues accessed in traces for both case histories.

APPENDIX 16

HYPOTHESES

Key: CON - confirmed; DIS - disconfirmed; UN - unconfirmed

1H

DIS 5. a fracture possibly ...
CON 6. if he d sort of rolled onto it, it is more likely to be soft tissue injury ....
UN 13. probably a contusion or ligament injury ...
CON 14. and the bruising and swelling ...
UN 53. maybe a com ensation problem ..
UN 54. or dangero s for him in this trade ...
UN 70. he might be working in a very dangerous area ..

2H

3H

CON 29. probably stop him working for a while ..

4H

5H

DIS 7. if he fell on outstretched hands it's quite possible he might have fractured ....
DIS 8. jarred joints ..
DIS 9. other joints ...
CON 10. on the other hand if he sort of rolled on it then it's more likely to be soft tissue injury ...
DIS 30. and suspect fractures
CON 35. it might be soft tissue

6H

DIS 107. and he's probably hanging it down ...
C N 114. probably when he stretches his hand out it's going to be tight
CON 116. obviously there's certain amount he can do
UN 117. but he'll be able to do a lot more when the stitches come out

7H

CON 108. all sorts of tissues could be involved
DIS 109. neuro tissues could be involved
DIS 110. median nerve maybe involved
DIS 113. if it came down it could be median nerve involvement there ...
UN 118. any of the major tendons could be involved ...
DIS 120. the stitches might not be too great
DIS 136. it might be pointing to circulatory problems
UN 165. this is probably restricted by a very tight scar

8H

DIS 22. tendons ..
UN 23. muscle ...

9H

CON 27. because it may be bandag d up ...
DIS 46. just looki g at this I'd be a bit dubious about the tendons and a nerve or two ..
CON 47. maybe not sliced in half but contusion and bruising ..

1A

UN 20. and there may also be other problems ....
DIS 21. she may have a balance problem
UN 67. either eyesight or ...
UN 73. perhaps her shoes are awful ....
UN 75. may e she's worn out her shoes ....
DIS 76. possibly her feet prorate
N 77. and ha e do e for years
UN 78. but they're only b g mning to give her pr blems now ...
UN 1 4. pro ably not terribly motiva d to exercises
UN 1 8. and I thi k she is probably li ed up for arthritis in this f t UN
UN 194. beca se unless she can walk properly she is going to get terrific biomechanic problems in

her back, knees, hips
UN 196. and she's going to overload the left side
UN 197. and be running into arthritic changes over there .....
UN 218. she really has perhaps affected the periosteum of the lower end of the fibula as well

<u>2A</u>

UN 33. probably from the initial trauma 8 years ago ..

<u>3A</u>

CON 116. if she has any arthritis in her joints ..
UN 189. she's probably fit
UN 190. but her bones will be thinning out any way ..
UN 260. obviously the gait will not improve significantly until she achieves particularly more dorsiflexion
UN 261. and her pain is reduced ..
UN 262. and probably reducing her swelling will help her range

<u>4A</u>

DIS 15. maybe ligaments ...
DIS 51. it might be unstable
CON 53. the problem could be because of laxity or muscle weakness
CON 61. she is probably stiff
UN 72. she might have proprioceptive problems too ..
UN 99. she'll get stuck ...
UN 100. adhesions .. things like that ...

<u>5A</u>

CON 76. I expect it to be pretty thick ..
CON 77. pretty swollen by now ...
UN 78. unpleasant ...
UN 84. now is that maybe a bit of bony ...
UN 85. something missed on X-ray?
UN 86. is there inappropriate movement of the joint?
UN 87. is it that it is still swollen?
UN 107. I'm sure proprioception will be down after this length of time
UN 122. but it might be laying down too much ....

<u>6A</u>

CON 48. so you'd automatically think ... lateral ligament sprain ....
CON 49. but it's just as well to check that there are no fractures

<u>7A</u>

CON 57. she may have some underlying osteoarthritis ...
UN 58. it may just be straight inflammation ....
UN 140. the laxity maybe recent
UN 141. it may be old
UN 150. it may be it's buried under the swelling
UN 151. and it hasn't come to the surface ...
UN 162. you can bet your bottom dollar that it's probably stiff as well

<u>8A</u>

CON 79. the swelling .. the bruising .. it is probably a soft tissue injury ..
UN 81. there might be more than a soft tissue injury but at this stage
CON 91. I suspect much of that is due to swelling
CON 92. and due to the pain ..
CON 128. the chances are there will be some involvement .. some discomfort ..

<u>9A</u>

UN 128. probably why she has repeated incidents of the problem ...

APPENDIX 17

Case I: treatments selected

TREATMENT	1H	2H	3H	4H	5H	6H	7H	8H	9H	ttl
Active exercise	X	X	X	X	X	X	X	X	X	9
Electrotherapy	X	X	X	X	X	X	X	X		8
Elevati n	X	X	X	X	X	X		X	X	8
Support	X	X		X		X			X	5
Advice	X		X	X		X			X	5
Massage	X						X		X	3
Ice		X			X			X		3
Contrast baths		X								1
Compression					X					1
Silicone							X			1
Total no. of treatments selected by subjects	6	6	4	6	5	5	5	4	5	

Case II: treatments selected

TREATMENT	1A	2A	3A	4A	5A	6A	7A	8A	9A	ttl
Electrotherapy	X	X	X	X	X	X	X	X	X	9
Active exercise	X	X	X	X	X	X			X	7
Elevation	X	X	X			X	X		X	6
Advice			X	X	X	X	X		X	6
Passive movements	X			X			X	X		4
Massage	X				X		X		X	4
Gait re-education		X		X		X	X			4
Compression	X			X	X	X				4
Ice		X			X					2
S pport				X	X					2
Mobilizations							X	X		2
Muscle strengthening	X									
Mobilize neural tissue							X			1
Orth sis	X									1
Total no. of treatments employed by subjects	8	5	4	7	7	6	8	3	5	

Key: ttl = total number of subjects using each form of tre tment

APPENDIX 18

SCRIPT ANALYSIS

Key: ET - electrotherapy; US - ultrasound; SWD - shortwave diathermy; PSWD - pulsed shortwave diathermy; OA - osteoarthritis; L - left; R - right

Case I. 1H.

Operation	Segment number	Contents
Collect	1-3	Time since injury; mechanism of injury
Hypothesise	4-6	Fracture?; soft tissue injury?
Collect	7-10	Prior care
Conclude	11-12	Not fracture; soft tissue injury
Hypothesise	13-14	Probably contusion; ligament injury; bruising; swelling
Conclude	15	Can help him
Collect	16-19	Pain; R/L hand
Interpret	20-23	Can function; important injury
Collect	24-31	Swelling; finger ranges; skin colour
Explain	32-39	Wary if colour suggested circulatory problems;
Collect	40-45	Dressings; skin broken; medication; occupation
Interpret	46	Needs both hands for work
Collect	47	Employment status
Interpret	48	Require rapid return to work
Collect	49-52	Previous injuries; work injury
Hypothesise	53-54	Compensation problem; danger at work
Collect	55-56	Mechanism of injury
Plan	57-59	Advice
Collect	60-63	Age
Explain	64-69	Exclude predisposing causes; advise about safety at work
Hypothesise	70	Dangerous occupation
Collect	71	Normal activities
Conclude	72-73	Heavy job requiring hands
Collect	74-77	Sporting activities
Conclude	78	Job requires hands
Method	79-89	Plan of examination
Collect	90-104	State of other joints; skin colour; skin temperature; swelling
Explain	105-106	Care re infection
Collect	107-117	Abrasions: state of, sutures, location
Conclude	118-121	Abrasions affect mobility; produce pain
Plan	122-123	Mobilise; reduce swelling
Explain	124-125	Prognosis depends on healing capabilities
Collect	126-131	Swelling; range
Method	132-136	Plan examination
Collect	137-139	Range
Conclude	140-142	Pain an swelling limiting motion
Plan	143-145	Laser; not US
Explain	146-156	Non-touch technique required; promote healing; dosage
Plan	157	PSWD
Explain	158	Inappropriate for small area
Plan	159-178	Elevation; massage; exercise; advice; support

Case I. 2H.

Operation	Segment number	Contents
Collect	1-8	Mechanism of injury; time since injury; occupation
Interpret	9-10	Nature of occupation
Collect	11-25	Mechanism of injury; associated injuries; R L hand; occupation
Plan	26	Back to work
Collect	27-35	Prior care; attitude
Interpret	36-37	Effect of attitude on treatment
Collect	38-44	Medication; pain
Interpret	45-49	Swelling; bruising; effects of lesion on treatment
Plan	50-59	Silicone; active exercise; US;
Collect	60	Age
Explain	61-65	Healing properties; infection
Plan	66-70	Silicone; US
Collect	71-76	Function (sport); time off work
Conclude	77-79	Back to work
Collect	80-84	Description of wound
Interpret	85	Messy
Collect	86-97	State of wound; swelling; pain; active movements
Conclude	98-100	Movement OK
Interpret	101-103	Acute; recent; swollen
Collect	104-107	Support; position hand held in
Plan	108-111	Elevation; ice; US
Explain	112-121	US dosage; promote healing
Plan	122-132	Advice; active exercise; support; not curapulse
Explain	133-135	No contact; water with US acceptable
Plan	136-139	Contrast baths
Explain	140-152	Sterile water; secondary intension healing; PSWD not practical
Plan	153	Interferential stimulation
Explain	154-159	Not practical
Plan	160-170	Warm water; active exercises; mobilisations; massage

Case I. 3H.

Operation	S gment n er	Contents
Collect	1-4	Main problem; mechanism
Explain	5-7	Structures damaged
Collect	8-15	Mechanism; pain; prior care
Interpret	16-17	Open; dirty
Collect	18-26	Time since injury· prior care; pain
Interpret	27-28	'Nasty' injury
Hypothesise	29	Stop him working
Review	30-33	Prior care
Collect	34-46	R L hand; pain;
Conclude	47-50	Site of lesion; pain
Explain	51-55	Pain; mechanical or inflammatory origin
Interpret	56-57	Bit of both
Explain	58-62	Pain; factors aff cting pain

Collect	63-66	Pain; support
Interpret	67-68	Elevation required
Collect	69 73	Pain
Explain	74-92	Pain pattern; affect on treatment; patient response
Collect	93-99	Pain pattern; occupation
Interpret	100-103	Nature of work; severity of injury
Explain	104-106	Secondary problems
Collect	107-115	Occupation; hobbies; other injuries; medication
Explain	116-119	Contraindications to treatment; level of analgesia
Interpret	120-121	Level of pain; treatment times
Explain	122-123	Normal function
Interpret	124-125	Active but not fine movements
Explain	126	Treatment objectives
Collect	127-136	Medication; swelling; lesion; skin colour; dressing
Explain	137-139	Tissues damaged; resultant problems
Collect	140	Bruising
Explain	141-144	Level of tissue damage; removal of dressing
Conclude	145-146	Swelling primary aim of treatment
Collect	147-155	Range; changes since injury
Conclude	156-157	Limitation due to swelling, tissue tension
Method	158-161	Measurement techniques
Conclude	162-166	Focus on increasing extension
Explain	167-173	Static muscle work to test contractile structures
Plan	174-176	Curapulse
Explain	177-178	Swelling
Plan	179-180	PEME; US
Explain	181	Affect healing and range
Plan	182-187	Active movements; US
Explain	188-213	Difference between US and PEME; dosages of PEME and US
Plan	214-218	Advice; elevation; hygiene

Case I. 4H.

Operation	Segment number	Contents
Collect	1-12	Age; time since injury; mechanism of injury; lesion; tissues damaged
Interpret	13-16	Chronicity; open lesion
Conclude	17	Tendons are OK
Explain	18-23	Type of injury
Collect	24-40	Work injury; prior care; tissues injured; range of movement immediately following injury; medication
Explain	41-46	Pain; effect on treatment
Collect	47-51	Dressings; sutures; other appointments
Interpret	52-56	State of wound
Collect	57	Infection
Explain	58-59	Selection of treatment
Interpret	60	Prophylactic medication
Explain	61-63	Reduce infection; assist repair
Plan	64-67	Not US
Collect	68-74	Swelling
Explain	75-78	Level of inflammation
Interpret	79-81	No infection; swelling respond to postural changes
Plan	82-84	Elevation; sling

Interpret	85-86	Mobility
Plan	87	Encourage to move
Explain	88-90	Movement to prevent shortening of structures
Collect	91-94	Occupation
Explain	95-97	Final aim of treatment
Collect	98-99	At work
Explain	110-102	Attendance for treatment; compensation; motivation
Collect	103-118	Range of movements; factors limiting range
Interpret	119-122	Has full range in joints
Plan	123-135	Encourage movement; ET to resolve inflammation; not accessory movements; exercise (active and passive)
Collect	136-144	General health
Explain	145-147	Contraindications to treatment
Interpret	148	OK
Conclude	149-150	Main problems - swelling and loss of range
Plan	151-153	Curapulse
Explain	154-165	Dosage; reasons for use; compared with megapulse;
Plan	166	Not US
Explain	167-169	Reasons
Plan	170-172	Passive movements
Explain	173	Stop stiffening
Plan	174	Active movements
Explain	175	Stop stiffening
Plan	176-191	Elevation; sling; advice

Case I. 5H.

Operation	Segment number	Contents
Collect	1-6	Time since injury; mechanism of injury
Hypothesise	7-10	Possibly a fracture; jarred joints; soft tissue lesion
Collect	11-15	Pain; L/R hand
Interpret	16-18	General function reasonable
Conclude	19-21	Important injury
Collect	22-26	Swelling; skin colour
Explain	27-36	Tissues injured; possibly soft tissue injury
Collect	37-44	Dressings; support; nature of lesion; medication; prior care
Conclude	45-51	Soft tissue problem
Collect	52	Occupation
Interpret	53	Need both hands
Collect	54	Occupation
Interpret	55	Back to work
Collect	56-61	Previous injuries; occupational injury; mechanism of injury
Plan	62-63	Advice
Collect	64-65	Age
Interpret	66-71	Young; warn of dangers of occupation
Collect	72-75	Hobbies
Interpret	76	Needs hands for work
Explain	77-89	Possible associated injuries
Collect	90-102	Skin colour; skin temperature; state of lesion; sutures
Interpret	103-110	'Nasty'; position affect mobility
Plan	111-114	Mobilise; reduce swelling
Collect	115-127	Swelling; range of movement; factors limiting movement
Plan	128-129	ET

Explain	130-133	Reasons for choice
Plan	134	Laser
Explain	135-146	Dose of laser; efficacy
Plan	147-149	US; Combine laser and US
Explain	150-152	US for swelling
Plan	153-156	Swelling
Explain	157-166	Reasons for selection and use of ET
Plan	167-169	Ice; elevation; active movements
Explain	170-173	Swelling
Plan	174-175	Compression pump
Conclusion	176	Reduce swelling a priority
Plan	177-181	Later treatments

Case I. 6H.

<u>Operation</u>	<u>Segment number</u>	<u>Contents</u>
Collect	1-7	Age; occupation; hobbies; currently working
Explain	8-12	Functional requirements of patient
Collect	13-37	Mechanism of injury; L/ R hand; open lesion; prior care; location of lesion; time since injury
Explain	38-42	Chronicity of lesion; prior care ; no fracture
Collect	43-61	Prior care; main problem; pain; stiffness; range of movement
Conclude	62-63	Stiffness and pain
Collect	64-68	Wrist stiffness; neural signs
Conclude	69-73	Stiff painful hand; open wound; examination limited
Explain	74	Nerve involvement
Collect	75-92	General health; occupation; medication; changes since injury occurred
Method	93-94	Plan of objective assessment
Explain	95-99	Infection
Collect	99-100	Tetanus immunisation
Explain	101-106	Infection
Hypothesise	107	Hand position
Method	108-109	Plan of objective
Plan	110-115	Stretching
Explain	116-124	Mobility increase with removal of stitches; medication as affecting treatment
Conclude	125-127	Main problem
Collect	128-150	Skin colour; condition of lesion; swelling; bruising; range of movement
Interpret	151-162	No infection; soft tissue shortening; swelling
Collect	163-165	Muscle strength
Plan	166-179	Active exercises; elevation; megapulse/curapulse
Explain	180-184	Reasons for use of ET
Plan	185-186	Decrease swelling and pain
Explain	187-198	Megapulse effects; dosage; IF
Conclude	199-201	Elevation; activity

Case I. 7H.

<u>Operation</u>	<u>Segment number</u>	<u>Contents</u>

Collect	1-19	Personal details; occupation; pain
Explain	20-29	State of tissue; tissues involved
Collect	30-37	Pain
Explain	38-40	State of the tissue; mechanical versus inflammatory
Interpret	41-44	Mechanical with some inflammatory element
Collect	45-52	Pain; L/R hand; diurnal pattern
Explain	53-57	State of the tissues
Collect	58-75	Present function; time since injury; mechanism of injury; prior care; changes since injury
Explain	76-80	Infection
Collect	81-91	General health; medication; prior injuries
Review	92-96	Swelling; pain; general health; medication
Interpret	97-103	Infection; no fracture
Collect	104-105	Nature of lesion
Method	106-107	Recording of information
Hypothesise	108-113	Nerve involvement
Collect	114-116	Neural signs
Hypothesise	118-120	Tendon involvement; skin condition
Collect	121-129	Swelling; skin colour; cleanliness; sutures
Interpret	130-133	Expected signs
Explain	134-139	Infection; circulatory problems
Interpret	140-141	No infection
Collect	142-143	Skin temperature
Interpret	144-147	Watch for infection
Explain	148-149	Wound break down if infected
Collect	150-154	Range of movement
Explain	155-158	Associated injuries
Collect	159-161	Range of movement
Explain	162-168	Active range limited
Collect	169-175	Passive range of movement
Interpret	174-176	Range not limited
Explain	177-179	Certainty about range in joints and tissue state
Collect	180-186	Range of joint movement; tension tests
Interpret	187-188	Intact but some tension likely
Method	189-193	Plan later assessment
Plan	194-198	Reduce swelling; soften scar; increase range; soap/oil
Explain	199-208	Value of treatment
Plan	209-210	Massage; not US
Explain	211-213	Reasons for US not being appropriate
Plan	214	US around lesion
Explain	215-218	Speed up healing; dose
Plan	219-220	Megapulse
Explain	221-226	Reasons; dose
Plan	227	Not IF
Explain	228-230	Reasoning about IF and US
Plan	231-239	Active and passive movements; resisted movements

Case I. 8H.

Operation	Segment n mber	Contents
Collect	1-12	Age; build; hand position; support; dressing; source of referral

Interpret	13-19	Painful; an accident
Hypothesise	20-23	Tendon or muscle involvement
Collect	24-37	mechanism of injury; time since injury; prior care;
Interpret	38-47	Accident; deep lesion; possible tissue involved
Collect	48-54	Swelling; bruising
Explain	55-57	Soft tissue damage
Interpret	58-61	Complicating factors
Collect	62-90	Medication; prior care; state of lesion; range of movements; factors limiting motion; L/R hand
Explain	91-96	Anti-inflammatories
Interpret	97-99	Tissue damage rather than infection
Explain	100-102	Soft tissue tightness causing problem
Method	103-105	Plan assessment
Collect	106-108	Passive joint range
Explain	109-113	Checking joint range
Interpret	114-115	Tissue tightness
Plan	116-123	PSWD; ice
Explain	124-125	Reduce inflammation; haematoma
Collect	126-127	Time since injury
Interpret	128	Acute
Plan	129-133	Active exercise; massage
Explain	134-143	No ice and PSWD not a problem; US later on; effects of PSWD
Plan	144-148	Active exercises; elevation

Case I. 9H.

Operation	Segment number	Contents
Collect	1-10	Age; occupation; L/R hand; hobbies; time since injury; mechanism of injury
Interpret	11-28	Function at work; power hand; general function; infection
Review	29-33	Age, time since injury; mechanism
Collect	34-44	Dressings; state of the wound; cleanliness; type of wound
Hypothesise	45-47	Nerves and tendons possibly injured
Collect	48-74	Condition of wound; swelling; colour; prior care; medication; function; sutures; pain
Review	75-78	Medical history; infection
Explain	79-87	Infection; need to preserve state of hands;
Collect	88	Tendons
Review	89-90	Had antibiotics and tetanus
Interpret	91	Cautious over usage
Collect	92-106	Neural signs; bruising; temperature
Interpretation	107-108	Inflamed
Plan	109	Watch for infection
Interpret	110	Mechanism of injury
Collect	111-118	Swelling
Interpret	119	Should have a sling
Explain	120-127	Problems with swelling and dependent limb
Plan	128	Movement a priority
Collect	129-134	Medical history; medication
Conclude	135-136	Can push him hard
Collect	137-139	General function; problems with being off work
Plan	140-143	Back to work as soon as possible but not make things worse
Collect	144-157	Range of movement; factors affecting range

Method	158-161	Plan assessment
Plan	162-169	Elevation; massage
Explain	170-171	Care but reduce swelling
Plan	172-177	Support; exercise; ET
Explain	178-179	Open wound; acute
Plan	180-182	Not US; possibly PSWD
Explain	183-188	Dose; doubt if needed
Plan	189-192	Advice

Case II. 1A.

Operation	S gment number	Contents
Collect	1-15	Gait; mechanism of injury; age; general stability; body build
Conclude	16-19	General problem; level and speed of recovery
Hypothesise	20-21	Other problems; balance problems
Conclude	22	Weight bearing
Collect	23-61	Swelling; bruising; history of injury; heart problems; medication; home situation; mental state
Conclude	62-65	Life situation; problems
Hypothesise	66-67	Additional problems leading to repeated trauma
Review	68-69	Senility; organic problems
Interpret	70-71	No CNS problems
Method	72	Examine shoes
Hypothesise	73-78	Problems leading to sprains (foot pronation, overweight, shoes)
Collect	79-82	Weight and hight
Interpret	83-87	Overweight, inactive, large number of sprains
Conclude	88-90	'Nasty' problem; unstable ankle; muscles weak
Collect	91-117	Nature of prior injury; pain; R/L injury; fracture
Conclude	118	Unstable ankle
Interpret	119-122	Generalised arthritis present; functional biomechanics normal
Collect	123-148	Foot pronation; present function; pain;
Conclude	149-153	Instability; recurrent; lateral ligament; compounded by age and inactivity
Hypothesise	154	Lack of motivation
Explain	155-158	Need for aggressive treatment; poor prognosis; OA likely
Method	159-162	Check pronation
Explain	163-167	Role of muscle in stabilizing joint
Method	166-167	Examine foot
Collect	168-184	Leg length; muscle wasting; gait; balance
Conclude	185-188	Biomechanical problem; gait problems
Interpret	189-193	No gross muscle wasting therefore improvement expected
Hypothesise	194-197	OA changes in gait not corrected
Collect	198-221	Joint range; swelling; pain;
Review	222-228	Frightened; elderly; overweight; inactive; biomechanical problem; relying on husband
Conclude	229-231	Confidence; swelling; movement
Plan	232-233	Pump
Explain	234-238	Reduce swelling
Plan	239 2 1	Elevation; massage

Explain	242-244	Swelling; confidence
Plan	245-248	Passive movements
Explain	249	Confidence
Plan	250	Ultrasound
Explain	251-265	Swelling; below malleolus; low dose; pulsed
Plan	266	Movement
Explain	267-269	Confidence
Plan	270-275	Stretch ligaments; orthotics
Explain	276-280	Excessive pronation; loss of strength; loss of ligament patency
Plan	281-285	Strengthen
Conclude	286-287	Swelling, pain reduction, confidence most important

Case II. 2A.

Operation	Segment number	Contents
Collect problems;	1-31	Time since injury; mechanism of injury; predisposing prior ankle injury and treatment;
Hypothesis trauma	32-33	Recurrent lateral ligament laxity; originating from prior
Interpret	34-38	Chronicity; delay in treatment
Method	39-42	Examination procedure
Plan	43-49	Frictions; stretches; US
Collect	50-60	Immediate care/casualty; pain killers; affect on sleep
Interpret	61	More acute than expected
Plan	62	No frictions
Interpret	63-64	Unable to tolerate frictions
Plan	65	PSWD
Interpret	66-69	Fairly acute; fairly painful
Collect	70-77	Work status; hobbies; uniqueness of injury; pain
Explain	78-92	Level of recovery required; severity
Method	93-99	Plan examination; visual observation; range; pain; gait
Collect	100-112	Joint range; pain; swelling; bruising
Interpret	113-122	Severe sprain; chronic; position of lesion
Method	123-125	Past observation
Collect	126-129	Sticks; gait
Plan	130-135	Ice; elevation; movement
Collect	136-137	Painful spots
Plan	138	Interferential stimulation
Explain	139-143	Swelling; pain relief
Plan	144	Degree of intervention
Explain	145-147	Little intervention; acute; painful
Plan	148-162	Gait; long term priorities (swelling; stability; gait; no ET)
Explain	163	ET not necessary
Conclude	164	Focus on function
Plan	165-171	Active exercise; gait; joint mobility; proprioception
Conclude	172	Level of intervention

Case II. 3A

Operation	Segment	Contents

	number	
Collect	1-11	Time since injury; main problem; mechanism of injury; pain; swelling; bruising
Interpret	12-26	Chronicity; severity; structures
Collect	27-33	Previous ankle injuries and treatment
Interpret	34-51	Frequency of injury; joint laxity; chronicity; efficacy of care
Collect	52-60	Prior treatment
Explain	62-67	Severity of problem; reports of prior tests; present interventions
Collect	68-79	Pain; R/L leg; weight bearing
Review	80-86	Pain; structures implicated
Interpret	87	Intermittent pain; mechanical problem
Review	88-90	Factors increasing/decreasing pain
Interpret	91-94	Mechanical problem; gait problem
Collect	95-102	Pain pattern
Review	103-112	Pain severity and patterns; treatment times
Collect	113	Age
Interpret	114-119	Arthritis
Collect	120-125	General health
Explain	126-132	Contraindications to treatment; general joint changes affecting treatment
Interpret	133-137	General swelling; weight affecting weight bearing
Collect	138-148	Employment; social conditions; hobbies; daily function
Interpret	149-150	Problems
Collect	151	Dressing
Explain	152-157	Previous function; present problems
Collect	158	Change in function
Interpret	159-162	Treatment objectives
Method	163-170	Special questions
Collect	171-176	General health
Explain	177-188	Selection of / contraindication to treatment
Hypothesis	189-190	Generally fit; osteoporosis likely
Interpret	191-194	Needs care because of age; reduced function
Plan	195-197	Return to previous functional level
Collect	198-214	R/L leg; swelling; skin condition; colour; range;
Interpret	215-238	Inversion injury; swelling affected by heart condition; skin delicate; range affecting gait
Collect	239-244	Range; strength
Explain	245-248	Passive range v. active range
Interpret	249	A little more passively
Explain	250-251	Static testing to examine muscle integrity
Interpret	252-253	Pain or weakness?
Collect	254	Gait
Conclude	255-256	Problem area: gait
Explain	257-259	Effect of range and strength on gait
Hypothesise	260-262	Gait will improve with change in range, pain, swelling
Plan	263-272	Pain; swelling; ice; curapulse; not massage
Explain	273-276	Curapulse to reduce pain and swelling; no contraindications
Plan	278	Elevation; exercises
Explain	279-280	Reduce swelling
Plan	281	Start with curapulse
Explain	282-2 6	Curapulse dosage
Plan	287-2 0	Active movements; gait
Explain	291-292	Expected changes
Plan	293-294	Gait

Conclude	295	Focus on pain, swelling, gait

Case II. 4A.

Operation	Segment number	Contents
Collect	1-6	Age; time of injury; mechanism of injury
Explain	7-13	Chronicity; tissues injured; level of treatment
Interpret	14-17	Inversion injury; ligaments; 'acuteish'
Collect	18-21	Pain; swelling; bruising
Explain	22-26	Level of inflammation; severity
Interpret	27-29	Ligamentous tear
Explain	30-34	Effects of pain on treatment
Collect	35-43	Mechanism; prior care
Interpret	44-46	X-ray
Collect	47-48	X-ray
Interpret	49-50	X-ray
Hypothesise	51-53	Joint laxity; weakness
Collect	54-55	Prior care
Interpret	56-57	Prior care
Collect	58-59	Physiotherapy appointment
Interpret	60-62	Effect of delay in treatment
Collect	63-69	Previous injuries; hypermobility
Interpret	70	Joint laxity
Plan	71	Strengthening required
Hypothesise	72-73	Proprioceptive problems
Collect	74-78	Present function; home situation
Explain	79-82	Approach to patient
Interpret	83	Needs encouragement
Explain	84-86	Treatment selection
Collect	87-93	Swelling; shoes; weight bearing
Interpret	94-98	Level of activity; healing
Hypothesise	99-100	Adhesions
Conclude	101	Need to mobilise
Collect	102-103	Range
Explain	104-109	Cause of limitation
Collect	110-112	Adhesions; 'bone pain'
Interpret	113-115	Ligament tear
Plan	116-119	Treatment selection
Interpret	120	Chronic
Collect	121	Muscle power
Interpret	122	Requires strengthening
Collect	123-129	Range; general health; weight; height
Interpret	130-134	Effect of height/weight on health
Collect	135-141	General health
Explain	142-143	Contraindications to treatment
Interpret	144	Nothing of consequence
Explain	145-147	Treatment aims
Collect	148	Skin condition
Explain	149-153	Selection of treatment
Collect	154	Circulation
Interpret	155-156	Care of skin
Plan	157-158	Aircast splint
Explain	159-164	Reduce oedema; increase stability
Plan	165-167	No US

Explain	168-171	Due to pain; might exacerbate condition
Plan	172-173	Curapulse; possibly interferential stimulation
Explain	174-177	Curapulse affect bone and collagen
Plan	178-179	Not interferential stimulation
Explain	180-181	Dosage
Plan	182-193	Passive movements; active exercises; gait re-education; elevation; advice; shoes

Case II. 5A.

Operation	Segment number	Contents
Collect	1-5	Age; time since injury; mechanism of injury; R/L leg
Review	6-10	Age; mechanism of injury
Collect	11-15	Mechanism of injury; pain; weight bearing
Interpret	16-17	Not likely to be fracture
Collect	18-19	Frailty
Interpret	20-21	Not likely to be fracture
Collect	22-28	Swelling
Interpret	29-31	Type of swelling
Collect	32-38	Gait; prior care
Interpret	39-45	Poorly advised
Collect	46-49	Prior care; pain killers
Interpret	50-55	Prior care
Collect	56-69	Prior care
Interpret	70-72	Prior care poor
Review	73-75	Three weeks since injury and no treatment
Hypothesise	76-78	Swelling
Explain	79	Prior care
Collect	80-81	Changes occurred since injury; reason for delay in treatment
Hypothesise	82-87	Fracture missed; joint laxity
Method	88-91	Subjective complete
Collect	92-94	Pain
Interpret	95-97	Ligaments, capsule, muscle possibly involved
Collect	98-100	Ability to stand on one/two legs
Method	101-106	Proprioception
Hypothesise	107	Proprioception
Plan	108-109	Proprioception
Collect	110-118	Range; pain
Interpret	119-121	Chronicity; scarring
Hypothesise	122	Scarring
Collect	123-126	Range
Interpret	127-136	Range
Collect	137-143	Range
Interpret	144-145	Degree of examination
Review	146-148	Time since injury; swelling
Plan	149-151	Reduce swelling
Collect	152-154	Bleeding; scabs
Plan	155-160	Ankle support; ice; massage; US
Explain	161-162	Tenderness; hands off treatment
Plan	163	SWD
Explain	164-167	Pain therefore pulsed SWD
Plan	168-171	Advice; active movements
Explain	172-173	Aim to restore movement to avoid later problems
Plan	174-176	Movement; ice
Explain	177-1 4	Availability for treatment; pain; swelling

Plan	185-192	Tubigrip; strapping; sticks; not cliniband

Case II. 6A.

Operation	Segment number	Contents
Collect	1-16	Age; R/L leg; occupation; home circumstances; normal function; time since injury; mechanism of injury; prior care
Interpret	17-22	Level of function needed; rapid mobilisation
Method	23-24	Plan of investigation
Collect	25-40	Prior care; gait; pain; swelling
Interpret	41-45	Pain and swelling a problem; gait poor
Plan	46-47	Defer examination of hip to later date
Hypothesise	48-49	Lateral ligament sprain
Interpret	50-56	Prior care
Collect	57-74	Swelling; pain; general health; medication; weight; gait
Interpret	75-84	In pain; reasonably fit for age
Collect	85-90	General health; pain killers; prior injury to ankle
Interpret	91-94	Instability; decreased proprioception
Plan	95-96	Prevention of repeated trauma
Method	97-103	Plan present examination
Collect	104-121	Swelling; gait; range; neural signs; pain; joint stability
Interpret	122-129	Movements limited; laxity; pain
Plan	130-141	Mobilise joint; decrease pain; improve gait;
Explain	142-147	Mobility; support
Plan	148	Community physiotherapy
Explain	149	Community physiotherapy
Plan	150-153	Advice; elevation; US
Explain	154-155	Pain; scar tissue alignment
Plan	156-157	Flowtron

Case II. 7A.

Operation	Segment number	Contents
Collect	1-7	Personal details; home circumstances
Explain	8-11	Functional needs
Collect	12-24	Pain; R L leg
Explain	25-30	State of tissue; inflammatory v. mechanical problem
Collect	31-44	Pain; present function
Interpret	45-47	State of tissue; inflammation
Collect	48-54	State of tissue on waking
Explain	55-56	Stiffness
Hypothesise	57-58	Osteoarthritis; inflammation
Explain	59	Tissue state
Collect	60	State of tiss e at end of day
Explain	61-63	Response to activity
Collect	64-67	Time since injury; mechanism
Explain	68-71	Tissue involvement
Collect	72-77	Pain; gait;
Explain	78	Degree of damage
Collect	79-84	Swelling; prior care; changes since injury
Interpret	85-89	Swelling

Collect	90-98	General health; previous foot injuries
Interpret	99-103	Joint laxity; factors affecting contraindications to treatment
Collect	104-105	General health
Method	106-123	Contents of objective assessment
Collect	124-137	Swelling; bruising; range of movement; tissue temperature; joint laxity; local tenderness
Interpret	138-139	Inversion injury; deltoid ligament
Hypothesise	140-141	Laxity recent/old?
Interpret	142-149	Laxity; lack of range
Hypothesise	150-151	Bruising
Interpret	152	Swelling related to medical history
Plan	153-155	ET; elevation; massage
Explain	156	Clear swelling
Plan	157-161	Massage; mobilisation of joint
Hypothesise	162	Stiffness of foot
Plan	163-165	Accessory movements; megapulse
Explain	166-168	Experience suggests megapulse better than US to reduce swelling
Plan	169	Interferential
Explain	170-171	Swelling; size of lesion
Plan	172-173	US locally
Explain	174-186	Comparison of US and megapulse
Plan	187-191	Advice; gait re-education; neuro-tension tape
Explain	192-194	Neural tension
Plan	195	Mobilise neural tissues
Explain	196-214	Good results with neural mobilisations; ET dosages

Case II. 8A.

Operation	Segment number	Contents
Collect	1-9	Age; height and weight; gait; R/L leg; complaint
Explain	10-19	Severity; type of injury; weight through injury
Collect	20-22	Shoes; swelling; bruising; distress
Method	23-27	Positioning of patient
Interpret	28	Fallen
Collect	29-46	Mechanism of injury; prior care; swelling; weight bearing; time since injury; changes since injury
Interpret	47-60	Accident; elderly; frail; little improvement
Collect	61-66	Medication (pain); present function
Method	67-68	Positioning of patient
Collect	69-78	Swelling; bruising; range of movement
Hypothesise	79	Soft tissue injury
Interpret	80	Local swelling
Hypothesise	81	Possibly more than soft tissue injured
Interpret	82-85	General swelling v. local swelling; occurrence of bleeding
Collect	86	Bruising
Interpret	87-90	Avascular structures; poor range, especially inversion
Hypothesise	91-92	Loss of range due to swelling and pain
Collect	93-104	Pain
Explain	105-112	Severity
Conclude	113-114	Lateral ligament injury
Collect	115-120	Swelling
Method	121-124	Plan of examination

Explain	125	Passive movement too painful to attempt
Collect	126-127	Straight leg raise
Hypothesise	128	Expect discomfort
Collect	129-133	Straight leg raise
Interpret	134	No neural tension
Method	135-136	Focus on ankle
Interpret	137	Swelling
Plan	138	Need to shift swelling
Interpret	139	Chronic
Plan	140-141	Interferential
Explain	142-144	Large area; swelling; chronic
Plan	145	Passive movements
Explain	146	Depending on pain levels
Plan	147-150	Mobilisations; PSWD
Explain	151-153	Chronic, large area, swelling : indications for PSWD
Plan	154	US locally
Explain	155-163	US and PSWD different; PSWD and IF similar
Plan	164	Gait re-education

Case II. 9A.

Operation	Segment number	Contents
Collect	1-12	Age; weight; time since injury; normal function
Explain	13-16	Effect on progress
Interpret	17-30	Joint problems; level of independence
Collect	31-41	Prior care; changes since injury
Explain	42-43	Need to know
Interpret	44-53	No fractures; gradual improvement
Collect	54-66	Swelling; skin colour; skin temperature; skin condition; vascular problems
Explain	67-80	Effects on treatment selection; infection
Collect	81-84	Shoes; walking aids
Conclude	85	Know what it looks like
Collect	86-97	General health
Conclude	98	No major surgery
Collect	99-113	General health; previous injuries to the ankle
Explain	114-120	Factors affecting response to treatment
Interpret	121-127	Effect of heart problem and old ankle injury on present return to normal
Hypothesise	128	Repeated ankle injuries
Interpret	129-137	Prior treatment for ankle injury when first damaged
Collect	138-158	General health; present function; home situation
Interpret	159-160	Poor function
Collect	161-168	Pain
Interpret	169-181	Poor function; lack of activity
Plan	182	Increase mobility
Explain	183-185	Approach to patient
Interpret	186	Elevation
Explain	187-188	Associated injuries
Interpret	189-204	Swelling; weight bearing problem; passive patient; joint problems
Method	205-213	Plan of assessment
Collect	214-231	Swelling; mobility; pain
Interpret	232-233	Arthritis; L=R
Method	234-237	Plan of assessment

Collect	238	Palpation
Interpret	239	Not reaching joint
Collect	240-247	Pain
Explain	248-254	Mobility; structures involved
Interpret	255-265	Swelling; muscles OK; pain
Explain	266-269	Seeking details of problem
Interpret	270-274	Localise structures involved
Collect	275-278	Mechanism of injury
Explain	279-286	Ligament testing; terminate examination
Plan	287-290	Elevation
Explain	291	Effect of gravity
Plan	292-295	Massage
Explain	296-298	Mobilise swelling; increase confidence
Plan	299	PSWD
Explain	300-301	Massage priority
Plan	302	US
Explain	303-317	US dosage
Plan	318-319	US plus PSWD
Explain	320-331	PSWD for swelling, pain; US locally
Plan	332-346	US; PSWD; shoes; elevation; active exercise
Explain	347	Proprioception
Plan	348-354	Muscle activity; tubigrip; shoes; not ice; not heat
Explain	355-358	Contraindications
Conclude	359-360	Movement priority

APPENDIX 19

Case 3A; Sample case to demonstrate sequential and cyclic information gathering

Cue elicited	Segmental location
Time since injury	1
Main problem	3
Mechanism	4, 5
Pain*	8, 72, 73, 75-77, 96-98, 100-102
Swelling*	9, 10, 209, 210
Bruising*	11, 205
History of foot problem*	27-33, 52, 53
Prior care	57-60
Weight bearing*	68, 70, 78, 79
L R leg*	74, 125, 199
Age	113
Present general health*	120-124, 172, 174
Medication*	123, 175, 176
Occupation	138, 139
Social circumstances	140-143
Present function*	144, 146-148, 157
Normal function	158
Medical history	173
Skin condition	203
Skin colour	205, 207
Range of motion*	214, 239
Muscle strength	241, 243, 244
Gait	254

* denoted cyclic information gathering